Figure 2-1. Aerial view of a farm site in Alachua Co. illustrating 50 m radius point count circle positioned on the edge of a cropped field where cropped field and field border habitat type were characterized. Matrix type adjacent to each field was characterized within a 200 m radius semicircle at each census point (after Freemark and Kirk 2001).

Figure 3-8. Birds foraging in crop vegetation were observed to consume numerous lepidopteran larvae as well as grasshoppers and beetles. Insects consumed by birds included Green Stink Bugs (*Acrosternum hilare*), Imported Cabbageworm (*Pieris rapae* - Linnaeus), and numerous Dipterans.

ASSESSMENT OF THE POTENTIAL FOR INTEGRATION OF AVIAN CONSERVATION WITH MODERN AGRICULTURAL PRODUCTION

BY

GREGORY ALAN JONES

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ASSESSMENT OF THE POTENTIAL FOR INTEGRATION OF AVIAN CONSERVATION WITH MODERN AGRICULTURAL PRODUCTION

By

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Chair: Kathryn E. Sieving, Associate Professor
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The overall goal of my research was to assess the potential for integrating bird conservation on farmlands while enhancing production goals through augmentation of insect pest control. Working on selected conventional and organic farms in North-central Florida my study objectives were to: 1) assess habitat characteristics on and adjacent to farms influencing avian species diversity and insect-foraging activity, and to identify 'functional insectivores' on these farms, 2) determine the effectiveness of sunflower intercrops as refugia for both insectivorous birds and beneficial insects in cropped fields, and as tools to enhance insect-foraging by birds in cropped areas, and 3) test the hypothesis that insectivorous birds can potentially augment pest control programs involving hymenopteran parasitoid predators, via preference for unparasitized over parasitized prey.

Using a combination of bird surveys and focal foraging observations over 2 years, I determined that bird diversity in cropped and non-cropped habitats on farms varied in the following ways: a) vegetation type in field borders significantly influenced species richness per census point ($F_{5,30} = 3.5$, $P = 0.013$) and in field borders ($F_{5,30} = 3.8$, $P = 0.009$), b) mixed crops generated significantly greater bird densities per point ($F_{1,30} = 7.4$, $P = 0.011$) and in cropped fields ($F_{1,30} = 8.2$, $P = 0.008$), and c) foraging activity and abundance of functional insectivores were greatest in mixed crops ($F_{1,29} = 4.2$, $P = 0.051$). In a replicated, controlled field experiment I determined that intercropping rows of sunflowers significantly increased densities of birds ($F_{2,200} = 43.33$, $p < 0.001$), numbers of individuals ($F_{1,196} = 59.84$, $p < 0.001$), and foraging time by individual insectivores in crops ($F_{1,196} = 51.93$, $p < 0.001$). Visual observations and stomach samples confirmed that birds consumed economically important pest insects. In experimental feeding trials, blackbirds exhibited no preference between parasitized and non-parasitized lepidopteran larvae of similar body size ($W_o = 139$, $p = 0.69$) but a significant preference for larger non-parasitized prey ($W_o = 248$, $p < 0.001$). My study suggests that farmlands can be managed to enhance wild bird populations and the potential that birds could augment pest control programs in modern agricultural operations.

CHAPTER 1
INTRODUCTION

The relationship of birds to agricultural activities in the temperate zones of the Northern Hemisphere has long been of interest to ornithologists both in the United States and in Europe. Early naturalists published numerous papers describing careful observations and thoughtful consideration of the relation of birds to crop production. During its existence, multiple reports produced by the Section for Economic Ornithology within the federal Department of Agriculture confirmed the utility of birds as destroyers of pest insects, often recommending their classification as highly beneficial to agriculture. However, with the advent of farm mechanization, synthetic chemical pesticides, and the intensification of agricultural production, focus upon the positive impact birds may have on agriculture waned and research interest regarding the detrimental effect agriculture has on avian populations increased. Currently ornithologists have suggested that change in agricultural practices and landscape structure over the past few decades have reduced the occurrence of farmland habitat elements many farmland species had traditionally utilized (O'Conner and Boone 1990, Freemark 1995, McLaughlin and Mineau 1995).

Rodenhouse et al. (1995) believe that agriculture has had a greater impact on the status of Neotropical migratory birds than any other human activity. Additionally, their review also shows that conservation measures benefiting avian species in

agricultural landscapes will be acceptable to farmers if management recommendations have neutral or positive effects on food production. Sufficient evidence has accumulated from studies in forest, grassland, orchard, and row cropping systems that offers sufficient evidence that insectivorous birds may be of economic value by enhancing production through predation of pest insects. Due to this potential ecological role of birds in agroecosystems, several reviewers of past work, including McFarlane (1976), Jackson (1979), and Kirk et al. (1996), suggest birds should be considered as components of modern biological pest management schemes. However, despite potential values of birds on farms, the theory and practice of enhancing these native natural enemies by providing habitat for them within cropping systems has been relatively neglected.

Ornithologists have an opportunity to propose management recommendations favoring avian conservation within agricultural production systems by working within interdisciplinary teams developing modern sustainable or natural systems agriculture (Rodenhouse et al. 1995). As agricultural producers recognize the importance of a structurally and biologically diverse farmed environment, ornithologists can institute the resurrection of quality avian habitat within agroecosystems. Enlightened management of farmlands can satisfy the needs of agriculture and numerous avian species while providing mutual benefits (Rodenhouse et al. 1995).

Economic Ornithology – The First Attempt to Integrate Bird Conservation and Agricultural Production

Early naturalists in this country, such as Alexander Wilson, James Audubon, and even Benjamin Franklin, became interested in bird behavior and made references

to the purely economic phases of bird life. Their writings repeatedly relate the value of different species as destroyers of insects. After 1850, various researchers interested in agriculture published numerous papers in agricultural journals and in reports of agricultural and horticultural societies that described careful observations and thoughtful considerations of the relation of birds to crop production (reviewed by Weed and Dearborn 1935). Needless to say, these publications generated a great deal of discussion as to the true utility of birds, because some bird species had long been considered agricultural pests.

One of the results of the organization of the American Ornithologist's Union (AOU; circa 1883) was the impetus it gave to the study of bird's food habits to resolve questions of their utility as pest predators and the desirability of legislation permitting the destruction of species popularly considered pests. At the request of the AOU and researchers within the Department of Agriculture, congress appropriated monies to establish a Section for Economic Ornithology (SEO) within the Division of Entomology of the federal Department of Agriculture (McAtee 1933). The section was responsible for the promotion of economic ornithology (or the study of the interrelation of birds and agriculture), the investigation of avian food habits, the investigation of both resident and migratory birds in relation to both insects and plants, and publish reports thereon (McAtee, 1933, Weed and Dearborn 1935).

Research emphasis at this time consisted of the examination of the contents of bird stomachs, together with observations of birds in the field. Multiple reports produced by the SEO confirmed the utility of birds as destroyers of pest insects and as important weed seed predators. Reports of this nature submitted to the USDA's

administrators often concluded that birds feed largely upon pest insects and should be classified among the species highly beneficial to agriculture. The section later developed into the original Biological Survey, and research of this kind continued until the early 1930s (Weed and Dearborn 1935, Kirk et al. 1996). However, with the advent of synthetic chemical pesticides in the 1940's, little work in this field has been done (Kirk et al. 1996). Currently, avian research performed by the USDA focuses, for the most part, upon control of crop damage by birds. While focus upon the positive impact birds may have upon agriculture waned, research interest regarding the detrimental effects agriculture has had on birds has increased since the 1940s.

Effects of Agricultural Practices on Avian Populations

Agricultural development since the 1700s has dramatically altered or eliminated the natural landscape of the continental United States. Forests originally covered about one-half of this region of North America, 40% was covered in grasslands, and the remaining area was arid and barren (Cochrane 1993). Between 1790 and 1890, 300 million acres of virgin forests were cleared and an equal amount of grasslands were plowed. Agriculture today comprises the largest landuse class encompassing over 50% of the arable land area of the contiguous 48 states (USDA 1998). Currently, of the 1.9 billion acres of land in the U. S., some 350 – 400 million acres are under intensive crop cultivation with approximately another 200 million acres of marginal land at the ready to be put into this practice should prices warrant its use (Cochrane 1993). While the conversion of natural landscapes to agroecosystems in Europe occurred much earlier in history, this alteration took place

steadily across several centuries, and agricultural lands now comprise 41% of the land area of the 15 countries of the European Union (Pain and Dixon 1997).

Agricultural practices on farmlands have changed drastically over the past 150 years. The concept of farm mechanization was widely accepted in the 1850s, characterized by the use of cultivators, mowing machines, and reapers (Cochrane 1993). From this point farm machines evolved rapidly; increasing in size and efficiency and incorporating both steam and then internal combustion power. Increased size and efficiency of farm machinery in the post World War 2 years allowed for the expansion of field size and homogenization in farmland structure. During the period from 1935 to 1970, while the acreage of land under cultivation did not change the number of farms declined from 6.8 million to 3 million via corporate consolidation concomitantly with an intensification of production per unit area (Cochrane 1993). This same phenomenon occurred in post World War 2 Europe including increased field sizes, reductions or elimination of boundary features, and an overall change in agricultural landscape structure (Pain and Dixon 1997).

Many researchers here in the U.S. have suggested that changes in agricultural practices over the past few decades have reduced the favorability of agricultural landscapes for foraging and nesting by many native and migrant species (Best 1986, O'Conner and Boone 1990, Warner 1992, Bollinger and Gavin 1992). The once heterogeneous landscape found in agroecosystems composed of woodlots, ponds, shelterbelts, wooded hedgerows and fencerows, and other such landscape elements provided for an abundance and diversity of bird species. However, these landscapes have become increasingly homogenized through the removal, fragmentation, and

isolation of these elements upon which many species had come to depend (O'Conner and Boone 1990). For example, Gawlick and Bildstein (1990) attribute the decline of Loggerhead Shrikes to loss of their preferred edge habitat in farm landscapes. This same sentiment has been voiced by researchers in Europe relating that increased specialization has reduced the prevalence of mixed farming and the habitat mosaics inherent to traditional types of farming (O'Conner and Shrubb 1986, Baillie et al. 1997). Groppali (1993) related the percentage of eradication of tree rows and hedges to expand cultivated parcels within his study area near Cremona, Italy, was 33% and 36% respectively over a 9-year period, 1980-1989. In these parcels where tree rows and hedges had been removed, species diversity and numbers of nesting pairs of birds were significantly reduced. In Britain, Baillie et al. (1997) found that more farmland birds are declining than increasing, and more importantly, specialist farmland species are declining more than generalists due to loss of preferred farmland habitat.

Within the U.S., resident and migratory landbird passerines, represented by over 200 different species, constitute over 70% of the bird species that feed, roost, or breed on agricultural lands (Rodenhouse et al. 1993). Most landbirds utilizing crop fields and edges are Neotropical migrants, and agricultural practices have been implicated in the decline of at least nine of these species currently listed as threatened or endangered. Studies in U.S. farm landscapes have found the majority of bird species utilizing agricultural lands are found in uncultivated areas. Highest species richness and abundance have been documented in those areas with greatest vegetative structure, including woody shrubs and trees. Avian richness and abundance are often lower in grassed edge, and lowest in row cropped fields (Shalaway 1985, Best et al.

1990, Camp 1990). Therefore there appears to be a strong correlation between decreasing species richness and abundance and decreasing structural diversity in farm systems. Similar results have been obtained in European studies (Baillie et al. 1997).

Production practices associated with agricultural intensification are also problematic for birds utilizing agricultural landscapes. Intensive agricultural practices include greater working of the land with quick rotations or relay cropping, cover crops replacing fallow rotations, increased livestock densities, and use of high yielding cultivars requiring greater or more frequent fertilization and irrigation (O'Connor and Boone 1990). Rodenhouse et al. (1993) indicated that Breeding Bird Survey abundances of many bird species in agricultural landscapes have exhibited significant negative associations with specific crops between 1973-1989, suggesting detrimental cropping practices are being employed. Multiple quick crop rotations within a year, or relay cropping, increases the frequency of disturbance during avian breeding potentially causing direct injury to adults and nestlings. Injury and nest destruction by farm machinery can occur during field preparation, planting, crop management, and harvest operations. Individuals can also be harmed indirectly through the application of herbicides and insecticides that alter vegetation structure and the insect food base within and immediately surrounding cultivated parcels (O'Conner and Boone 1990, Rodenhouse et al. 1993). In their publication *Birds in Europe*, Tucker and Heath's (1994) analysis of the major threats to birds listed as species of conservation concern showed that agricultural intensification affects more species than any other threat.

Birds as Predators in Agroecosystems

While the detrimental effects of modern agriculture on birds has received much attention, the importance of wild bird management to enhance the productivity and sustainability of agriculture, or to maintain ecological integrity and biodiversity in agroecosystems, has not been thoroughly investigated (Rodenhouse et al. 1993, Kirk et al. 1996). Rodenhouse et al. (1993) suggest that the development of lower input sustainable agriculture and acceptance of integrated pest management (IPM) programs may offer opportunities for greater avian conservation in agroecosystems. Most importantly, management of uncultivated habitats (where birds may thrive) to preserve natural enemies of agricultural pests will become a central part of pest management planning in IPM (Rosen et al. 1996). The conservation value for bird species utilizing low-input agricultural landscapes will be realized through the reestablishment of habitat (i.e. Woodlots, windbreaks, complex hedgerows, etc.) and an increase in food resources enhancing both their survival and reproductive success. Rodenhouse et al. (1995) believe that the key to acceptance of conservation measures that benefit avian species in agricultural landscapes is that management recommendations do not interfere with, and hopefully enhance, production. Here lies an important opportunity for ornithologists. By illustrating that birds may be of economic value by enhancing production through predation of pest insects, farmers could be encouraged to consider providing habitat for these species in their cropping systems and farm landscapes.

Studies relating individual pest species to individual bird species or groups of species offer sufficient evidence that birds can and should be considered as an

important component of modern biological pest management schemes (Jackson 1979). Birds are important predators of many destructive forest insects and play an important role in suppressing phytophagous insect populations in forest ecosystems (reviewed by Takekawa et al. 1982, McFarlane 1986, Price 1987). Moreover, via numerical and functional responses to insect outbreaks in North America birds are potentially decreasing insect outbreak frequency and severity (Holling 1988, Dahlston et al. 1990, Holmes 1990). Limitation of phytophagous insect biomass in these systems may have an important effect upon primary productivity within forest systems. For example, Marquis and Whelan (1994) have demonstrated that exclusion of insectivorous birds from foraging on phytophagous pests of white oak in Missouri significantly reduces long-term primary productivity of individual trees. Over several years, trees harboring insectivorous birds had greater leaf area and stem elongation than did trees where birds were excluded or in trees that were sprayed with insecticide. Conceivably, birds utilizing agricultural areas could provide similar biomass reduction and productivity benefits, which could be realized through appropriate management practices (Rodenhouse et al. 1995, Kirk et al. 1996).

Over the past 10 years, field entomologists and agronomists have increasingly recognized that conservation of natural enemies via management of non-cropped habitats that support them is important to effective and successful biological control in agricultural systems (Rosen et al. 1996). However, despite its demonstrated value, the theory and practice of enhancing native natural enemies as integral components of agroecosystems has been relatively neglected (Picket and Bugg 1998). If a low-input productive balance is to be restored within agroecosystems, farmers must recognize

and make use of natural control of insect pests by providing for the needs of all potential predators of pest insect within these systems. As was recognized long ago by economic ornithologists, most birds that traditionally utilize agricultural areas may be of great economic value by providing biological stability in agroecosystems. Conservation of beneficial insectivorous birds through habitat enhancement on farms could result in significant economic benefits to agricultural production by reducing pest control costs and improve sustainability through reduced reliance upon persistent toxic agrochemicals.

Examples of Experimental Work Investigating the Impact of Birds on Insect Populations in Modern Agroecosystems

Since 1950, several studies have focused upon 2 pests of field crops, corn borers and grasshoppers, utilizing exclosures to compare insect populations protected from bird predation (Kirk et al. 1996). Both Floyd et al. (1971, 1969) and Black et al. (1970) reported significantly lower survival of overwintering corn borer larvae found in corn stalks exposed to bird predation compared to those present within exclosures. As overwinter losses were normally low due to other factors, they concluded these were destroyed via predation by birds [such as Northern Flickers (*Colaptes auratus*)] observed feeding on corn stalks. Numbers of larvae removed compared with the numbers remaining in infested stalks where birds had been excluded ranged from 45% to over 80% in these studies. Quiring and Timmins (1988) found similar results of reduced corn borer larvae overwinter survival due to predation by American Crows (*Corvus brachyrhynchos*) in southwestern Ontario, Canada. Additionally, corn borer

larvae removal was found to be greatest in those fields nearest one of the largest known crow roosts in the region.

Exclusion studies of bird predation impact upon grasshoppers in rangeland systems (frequently grasslands are interspersed with row cropping fields) have produced mixed results. While Belovsky et al. (1990) determined birds had a minor impact on grasshopper populations, other studies indicated that birds do affect grasshopper densities and species richness. Joern (1986) concluded that avian predation can have a significant impact on grasshopper populations through biomass reduction and reduction of species diversity. Modeling this, Kirk et al. (1996) estimated that a grasshopper-eating passerine family unit could consume 3.7 kg of grasshopper biomass, or approximately 149,000 individuals per breeding season. In a grassland system of Northwest China, numbers of breeding Rosy Starlings (*Sturnus roseus*) were increased after human made nesting sites with shrubby cover and water were added (Olkowski and Zhang 1998). Researchers determined grasshopper numbers were reduced from 42 to 2.3 per m^2 within a 500 m radius around artificial nesting structures by the end of the birds' breeding season (Chen 1986, Olkowski and Zhang 1998).

Two recent exclosure studies have evaluated the impact of bird predation on foliage arthropods in coffee plantations and lepidopteran pests in an orchard system. Greenberg et al. (2000) found birds reduced the abundance of large arthropods on coffee plants by 64-80%, compared to that those found on plants where birds were excluded, depending on the coffee system type (shade or sun coffee). A significant reduction in leaf damage to coffee plants was associated with this reduction in

arthropod biomass in both coffee systems. Mols and Visser (2002) found that caterpillar damage levels to apples in orchards decreased with increased periods of foraging by great tits (*Parus major*). Overall damage to apples by caterpillars was reduced by measurable amounts improving yield, number of apples per tree, compared to trees where great tits were excluded.

Both McFarlane (1976) and Kirk et al. (1996) conclude that strong experimental evidence in forest and grassland systems suggests avian predation could suppress crop insect pest populations at medium or low infestation levels, representing an important ecological in agroecosystems would compliment integrated pest management plans. While birds alone may not "regulate" insect pest populations, combined with other forms of pest management, they promise to play an important ecological role in agroecosystems (Kirk et al. 1996). Sympathetic management is needed to stem the decline of farmland birds and enable them to assume a mutualistic role with agricultural production.

Natural Systems Agriculture or Ecoagriculture

Agricultural modernization largely contradicts ecological principles. Consequently modern, or "conventional", agroecosystems are inherently unstable, plagued by recurrent pest outbreaks, pollution of water systems, soil erosion, salinization, and other undesirable environmental and social costs (Altieri 1994). Modern agriculture emphasizes artificial single species monocultures, requiring constant human intervention to suppress ecological succession and maintain productivity (Swift and Anderson 1993). Additionally, simplification of species

composition of biological communities both reduces their stability and results in increased susceptibility of that community to invasion by undesirable species (Elton 1958, Crawley 1987). Therefore, conventional agriculture exists in a metastable equilibrium regulated by enormous inputs of energy (Harwood 1990) and human activity (Gliessman 1987). The inherent self-regulation of populations within natural biotic communities is lost when humans modify community interactions and disrupt coevolutionary processes (Turnbull 1969). Inherent limitations of species populations within natural communities is a desirable attribute to incorporate into synthetic agroecosystems (Turnbull 1969) and, in particular, enhancement of predator-prey relationships characteristic of natural systems has a pivotal role to play in the evolution of agriculture towards more environmentally sustainable systems in this century (Atkinson and McKinlay 1997).

An ecosystem approach to agriculture emphasizes management of agroecosystems in such a manner that sufficient food production will be sustainable and of high quality with minimal environmental disturbance (Colby 1990, McNeely and Scherr 2003). Utilizing this approach, it is believed that a multitude of beneficial ecological processes can be incorporated into agroecosystems (Soule and Piper 1992). The central idea for "ecological agriculture" is that the structures of native biological communities are the most appropriate structural models for agriculture. Such communities have developed and endured in particular environments as a result of centuries of evolutionary selection for ecosystem function (The Land Institute 1999, McNeely and Scherr 2003). Agricultural systems that are modeled after natural ecosystems should exhibit many functional attributes and processes that stabilize

natural systems, including vegetation adapted to the local climate, closed nutrient cycling, effective resource partitioning, soil preservation, and biological methods of crop protection (Soule and Piper 1992). Therefore, by mimicking the local natural vegetation structure of native biological communities, farmers can emulate a whole package of patterns and processes that have developed over an evolutionary time frame exhibited by these ecological systems. Additionally, rather than perfecting one crop at a time, this holistic ecological perspective to agricultural production suggests seeking out a collection of plants and animals that work well together. It is this perspective of natural systems agriculture that provides a great opportunity for avian conservation.

The potential exists to manage farm habitats to attract selected desirable species in greater numbers in order to create a stable guild of insect predators, capable of rapid aggregation to high density "hot spots" of colonizing pests, and capable of switching to pest species from alternative foods (Helenius 1998). Methodologies that promote the abundance and diversity of pest insect predators will not only significantly contribute to non-chemical based crop protection but also provide beneficial consequences in conserving biological diversity in agricultural landscapes. Habitat management to enhance biological control of arthropod pests can provide various environmental requisites to pest insect enemies (such as birds) including modified climate, protective cover, nesting habitat, and supplementary foods (Pickett and Bugg 1998). Colonization, dispersal by diffusion, and foraging movements of beneficial predators can be influenced through habitat modifications within cropping systems (Helenius 1998). For example, weedy vegetation strips within fields could

be arranged in such a way as to provide refuge and increase interspersion of foraging predators within large cropped areas (Nentwig 1998). Modifying agricultural landscapes, or "farmscaping," by adding features such as hedgerows, field margins, shelterbelts, and roadside and watercourse plantings using native trees, shrubs, perennial grasses, and herbaceous and annual broadleaf species can attract and sustain beneficial arthropod pest predators (Bugg et al. 1998).

Ornithologists have an opportunity to propose management recommendations favoring avian conservation within agricultural production systems by working within interdisciplinary teams developing modern sustainable or ecoagriculture. The largely unexplored diversity of avian insect predators that could be included in natural biological regimes offers numerous possibilities for their use in cropping systems. Birds of conservation concern, both resident and migratory, can benefit from cropping systems and farmland habitat structure created to enhance insectivorous bird use of agroecosystems. Through this effort, many habitat features and the structural complexity once found within agricultural landscapes supporting avian species in the past would be reintroduced. As agricultural producers recognize the importance of a structurally and biologically diverse farmed environment, ornithologists can institute the resurrection of quality avian habitat within agroecosystems. With enlightened management of farmlands both the needs of agriculture and numerous avian species, as well as other wildlife, can be satisfied and mutually beneficial (Rodenhouse et al. 1995).

Research Needs

Before we can propose that agricultural producers can truly employ birds in pest management schemes we must not only know the relationship between insect pests and avian species, we must have an understanding of the functional role birds currently play in modern agroecosystems. With this understanding, management recommendations for biological control enhancement can be developed by manipulating populations of avian species identified as potentially beneficial currently existing in, or that could be attracted to, these systems. Rodenhouse et al. (1995) state that future research should focus upon identifying farmland structures and agricultural practices that create and sustain avian populations. They explain that studies of annual breeding productivity and survival of birds nesting in fields and edges are few, potential source areas that may require protection or expansion have not been identified, and the values of specific landscape elements and combinations of elements have not been determined for agroecosystems. Therefore, they believe that both field-scale and landscape scale studies need to be performed and integrated.

Kirk et al. (1996) believe that a consideration of birds should be part of any economic cost/benefit assessment related to pest control programs and farm landscapes should be managed with them in mind. They state that more multidisciplinary studies are needed to examine: (1) the abundance and availability of birds relative to various insect pest species, (2) avian diets and foraging habits to determine quantitatively the site-specific level of predation on invertebrate pest species compared to other arthropods, (3) integration of birds with other natural insect enemies, and (4) management of farmland landscapes in ways that best augment

natural control of insect pests. Wratten et al. (1998) indicate the potential for the expansion of research exploiting ecological knowledge in farmland management is promising. They suggest that a better understanding is needed of 3 related processes: (1) the spatial scale dynamics of beneficial insect predators on farmland, (2) the potential negative effects of insect predator refugia, and (3) the mechanisms involved in the functioning of within-field and border refugia for the enhancement of natural enemies of insect pests in agroecosystems.

Conclusion

Ornithologists have suggested that change in agricultural practices and landscape structure over the past few decades have reduced the favorability of farmland habitat elements many farmland species had traditionally utilized. Agricultural landscapes have become increasingly homogeneous through the removal, fragmentation, and isolation of these elements upon which many species had come to depend. Intensification of agriculture, resulting in changes in production practices, has also been cited as being problematic for birds utilizing agricultural landscapes. Direct injury to individuals and nest destruction can be caused by farm machinery during cropping operations. Individuals may also be harmed indirectly through the application of agrochemicals. Holistic ecological perspectives to agricultural production of both sustainable and natural systems agriculture provide an opportunity to promote the inclusion of suitable habitat in agricultural lands for avian species. Farm habitats can be managed to attract desirable insect pest predator species in greater numbers contributing to non-chemical based crop protection as well

as improve conservation of biological diversity in agricultural landscapes. Migratory and resident species of conservation concern will also benefit from farm structure and management created to enhance avian presence in agroecosystems.

Recommendations developed by the ornithological community integrating the body of information defining the problems faced by farmland birds with research illuminating the functional role birds play in these systems, can potentially reverse agricultural practice-induced avian population declines. Aldo Leopold stated,

> In its extreme form it [agriculture] is humanly desolate and economically unstable. These extremes will someday die of their own too much, not because they are bad for wildlife, but because they are bad for farmers. When that day comes, the farmer will be asking us how to enrich the wildlife of his community. (Leopold 1945, page 168)

As imperatives for agricultural shift from the single goal of increasing production per acre to environmentally sustainable systems, an excellent opportunity exists to match the aspirations of farmers with needs of birds of conservation concern.

CHAPTER 2
AVIAN BIODIVERSITY AND FUNCTIONAL INSECTIVORY ON NORTH-CENTRAL FLORIDA FARMLANDS

Introduction

Although agroecosystems do not support the biodiversity of natural landscapes they replace, under the right circumstances they can provide diverse ecological functions in addition to habitat for wild species. In regions where urbanization is rampant (e.g., Florida) farmlands are often the only ecological buffer between natural ecosystems and suburban sprawl (Evans and McGuire 1996, McNeeley and Scherr 2002). Reflecting growing public concerns over scientific reports of agriculture's negative effects on human and ecosystem health (e.g., Parsons et al. 2000) during the past decades, policy makers have been responding with incentives to modify grower operations to reduce negative environmental impacts and increase ecological values of farmlands (Ikard 1996, D'Souza and Ikerd 1996). For example, USDA programs like SARE (Sustainable Agriculture Research and Education) promote development of sustainable agricultural practices through research partnerships between farmers and scientists (http://www.sare.org/htdocs/sare/about.html). Additionally, the Farm Bill of 2002 provides farmers monetary incentives for conservation of soil, water, air, and biodiversity (Farm Security and Rural Investment Act of 2002). Signs of change toward ecological agriculture include an increase of 10% per year in US farmland acreage under certified organic management (USDA 1996, 2000, 2001a). With the public, policy makers, and

farmers increasingly involved in exploring alternative agriculture, the need for research to integrate production of ecological services, native biodiversity, and healthy foods is also intensifying (Rodenhouse et al. 1995, McNeeley and Scherr 2002).

Wildlife conservation is a natural partner in cultivating ecological agriculture (Vandermeer and Perfecto 1997, McNeeley and Scherr 2002), yet this partnership is weak because conventional food production practices that are detrimental to biodiversity still dominate, and because research has not been satisfying demands for information for ecologically-oriented farm operations (Hess 1991, Alston and Reding 1998, Jacobson et al. 2003). Habitat destruction for agricultural expansion remains the single most important cause of biodiversity impoverishment the world over (Vitousek et al. 1997), and if native biotas are to survive the coming decades of human population expansion, agricultural production lands must improve their biodiversity-holding capacity (Pimental et al. 1992, Hobbs and Norton 1996). Indications are that alternative agriculture practices encourage native wildlife and protect ecosystem services better than conventional production agriculture (Warburton and Klimstra 1984, Pimental et al. 1992, Uri et al. 1999, McNeely and Scheer 2002), in part because sustainable farming generates heterogeneous vegetative environments with features (hedge rows, shelter belts, mixed cropping systems, and plantings that host natural enemies of pest species; O'Conner and Boone 1992) that encompass many recognized values for both wildlife and people (e.g., wild flowers, pollinators, and game; Daily 1997a). Conventional agriculture, however, still dominates human landscapes in the developed world, to the detriment of native biodiversity. For example in the U.S., over 200 native species of resident and migratory birds feed, roost, or breed on agricultural lands (Rodenhouse et al. 1993), but many of

their populations decline by 50% or more where expansive monocropping systems with short rotation periods, heavy chemical inputs, and intensive mechanization reign (O'Conner and Shrubb 1986, Rodenhouse et al 1993, Freemark 1995, McLaughlin and Mineau 1995; bird declines in Europe - see, Pain and Dixon 1997, Pain and Pienkowski 1997, Ormerod and Watkinson 2000).

Ecological research on farmlands would help the shift to ecologically sustainable agriculture, but research to foster ecological integrity on farms is scarce (Cochrane 1993, McNeely and Scheer 2002), despite numerous encouraging factors: 1) considerable public interest, 2) diverse ecological values of farmlands, 3) an enormous area on the earth's surface in which to work (950 million acres in the U.S.; USDA 1999), 4) global biodiversity conservation needs to prioritize farmlands, because current parks and reserves are insufficient and, 5) farmlands are relatively easy to restore to native ecosystems (Askins 2000, McNeely and Scheer 2002). One reason for lack of interest in conservation research in agroecosystems is that agriculture is a business and ecologists have largely failed to show how biodiversity conservation and ecological functionality can realize economic benefits for growers (Daily 1997b, McNeely and Scheer 2002). A priority area of interest to growers has always been pest control. Whereas bio-control programs focus primarily on invertebrate predators on pests, little work has been done to integrate vertebrate species into row crop agricultural systems. In this study I assessed the potential that native bird species could serve as effective predators of pests. I examined factors influencing avian species diversity on North-central Florida farmlands and, in particular, factors that increased insect-eating activity by wild birds in cropped fields. Goals for this study were two-fold: 1) to assess overall avian biodiversity (species

richness and densities) on a selection of conventional and certified organic farms, and identify farm characteristics (management and vegetative structural features) correlated with bird diversity, and 2) to identify 'functional insectivores' among the bird species utilizing farmlands (or, those species that we observed to feed frequently on insect prey in cropped fields), and to identify farm characteristics (management and vegetative structural features) correlated with the densities of functional insectivores in cropped fields.

Study Design

Certified organic farming is defined as crop production without the use of most conventional pesticides, synthetic fertilizers, sewage sludge, or bio-engineered food plants (USDA 2002). Other works have shown that both birds and insect biomass can be higher on organic, or low input, than conventional farms (birds: Christensen et al. 1996, Chamberlain et al. 1999, Freemark and Kirk 2001, Beecher et al. 2002; insects: Dritschillo and Wanner 1980, Hald and Reddersen 1990, Brooks et al. 1995, O'Leske et al. 1997, Feber et al. 1997 & 1998). Therefore, in this investigation of factors affecting bird diversity, abundance, and insect foraging paired sampling sites were selected on both organic and conventional farms. In addition to censusing the bird community over 2 years (2000 and 2001), extensive foraging observations were conducted on individual birds in cropped areas, and both field scale features (crop type, field border vegetation) and type of matrix adjacent to each sampled field were characterized as predictors of both bird diversity and foraging activity on the two farm types. I define functional insectivores as bird species that were observed most commonly feeding on insect prey taken from crop vegetation. All of my study species have been classified in the literature

according to well-established foraging guilds (e.g., frugivore, insectivore, omnivore) based on their most typical or average annual diet composition across the US (De Graaf et al. 1985). However, many birds' diets vary with season, and both typical frugivores and omnivores can be highly insectivorous during breeding efforts (Beal et al. 1941, Martin et al. 1951, Ehrlich et al. 1988). Therefore, rather than using 'typical' dietary guilds to classify how birds might be interacting with insect pests, I wanted to know which species were frequently out in fields eating insects during the spring growing seasons on the farms studied. The most abundant of these insect-foraging species were designated as functional insectivores – or those most likely to consume insect biomass with positive economic outcomes for farming operations.

Methods

Research Site Selection

With the aid of University of Florida Cooperative Extension agents, and following farmer participation in surveys (see Jacobsen et al. 2003), local producers were contacted to obtain permission for conducting research on their properties. A total of 30 census points were established on certified organic farms during April of 2000, and a paired reference site for each of these points on a nearby conventional farm was established (n = 60 total points, 10 organic and 10 conventional farm properties) in an effort to match crop types, habitat structure, field border types, and matrix vegetation where possible (after Rogers and Freemark 1991, Christensen et al. 1996, Chamberlain 1999). In 2001, one of the organic farms sampled in 2000 was not planted, thus 5 fewer points were used in the second year of the study. The 20 farm properties ranged in size from 4 to 104 ha located within Alachua, Gilchrist, Marion, and Jefferson Counties of North-central Florida.

Patterns of Bird Diversity

Census surveys

Surveys were used to estimate bird species richness and density in cropped and non-cropped habitats on farms. Birds were censused utilizing point count methods described in Bibby et al. (1992) with modifications recommended by Freemark and Rogers (1995) to suit agricultural landscapes. Sampling points of 50 m radius (fixed) were situated on the border of cropped fields with non-cropped areas (Figure 2-1). Census points were at least 200 m apart if they occurred on any single farm management unit. All points were sampled a minimum of 4 times between 25 April and June 30 in both 2000 and 2001, and order of visitation to sites in the pair (organic vs. conventional) and the order of points visited on each farm management unit were reversed each visit. Censuses were conducted between dawn and 1100 EST on fair weather days. All birds seen or heard within the 50 m fixed-radius during a 10 min period were recorded. Registrations were recorded and mapped onto two 180° semi-circles (in the cropped field and the un-cropped area – after Freemark and Rogers 1995; Figure 2-1). By marking the locations of individuals and noting their movements on maps this minimized the potential of double counting individuals during counts. By censusing in this manner, I quantified bird occurrences, both within cropped areas close to field edges and in adjacent non-cropped habitats.

I began counting 2-3 minutes after arriving at each station. Birds occurring outside of the circles or flying overhead were noted (see below) but excluded from point count data, with one exception; I considered swallows or purple martins flying low (< 10 m above vegetation) over fields to be 'using' them (since they are likely to be foraging on

Figure 2-1. Aerial view of a farm site in Alachua Co. illustrating 50 m radius point count circle positioned on the edge of a cropped field where cropped field and field border habitat type were characterized. Matrix type adjacent to each field was characterized within a 200 m radius semicircle at each census point (after Freemark and Kirk 2001).

insects; see Boutin et al. 1999). Birds flushed within a count circle as an observer approached or left a station were counted if they were not otherwise recorded during the count period. If a flock was encountered, it was followed after the end of the sampling period (if needed) to determine its composition and size. Because sampling occurred during the breeding seasons only, singing males observed repeatedly during counts were assumed to be paired breeders and were counted as two individuals (after Bibby et al. 1992). Walk-abouts were conducted in cropped and non-cropped areas on each farm unit following point counts (Freemark and Rogers 1995). Only species not noted during the formal point counts were recorded during walk-abouts.

Habitat classification: field-scale features and adjacent matrix type

Habitat characteristics associated with each census point were assessed at field edges and in surrounding matrix (Figure 2-1; refer to Table 2-1). Field scale characteristics of the farms were classified within each 50 m census point and included whole-farm management type (certified organic or conventional), crop diversity (mixed or mono crops), and field border habitat types (see Table 2-1). Matrix types that dominated the immediate area adjacent to fields sampled were characterized within a 200 m (6.3 ha) radius semi-circle adjacent to the cropped field edge (see Freemark and Kirk 2001, Figure 2-1, Table 2-1). The dominant matrix type was identified as the one habitat type covering the largest area within the 200 m semi-circle. Area of each matrix type was measured within the semicircle plot utilizing ESRI ArcView software and the Xtools extension package (Oregon Dept. of Forestry 2001) and 1999 digital ortho quarter-quad aerial photos obtained from the Florida Department of Environmental Protection. Of the

Table 2-1. Predictor and response variables used in analyses. The representative scale of measurement for each predictor variable is indicated in column 3. See text for clarification.

Variable	Categories	Scale	Definition
Predictor Variables			
Year	2000		Time (2 levels) included as
	2001		repeated measure in analyses
Farm type	Conventional	Whole Farm	Conventional management
	Organic	Whole farm	Certified organic management
Crop	Mono	50 m radius census plot	Single crop species in field
Diversity	Mixed	50 m radius census plot	2 or more crop species in field
Border type	Crop	50 m radius census plot	Cultivated field in production
	Hardwood	50 m radius census plot	Broad-leaved trees > 5 m tall
	Hedge	50 m radius census plot	Linear strip of woody vegetation
	Pasture	50 m radius census plot	Improved grassland: grazed
	Suburb	50 m radius census plot	Residential development
	Pine plantation	50 m radius census plot	Slash pine trees > 5 m tall
Matrix type	Crop	200 m radius semicircle	Cultivated field in production
	Hardwood	200 m radius semicircle	Broad-leaved trees > 5 m tall
	Pasture	200 m radius semicircle	Improved grassland: grazed
	Suburb	200 m radius semicircle	Residential development
	Pine plantation	200 m radius semicircle	Slash pine trees > 5 m tall
Response Variables			
Density *		50 m radius census plot	Mean # of birds / ha
Species richness *		50 m radius census plot	Total # of species counted
Insect-foraging observed **		50 m radius census plot	Categorical (yes / no)

* 3 measures taken: whole point count circle, crop half, and field border half of circle.
** Only in crop half of point count circle.

five matrix types (Table 2-1), the mean coverage for each primary matrix type was never less than 62% (max 90%) of the 200 m radius semi-circle.

Determination of functional insectivores

In order to identify those species exhibiting the greatest potential as arthropod pest predators in cropping systems a minimum of two 1-hour *ad libitum* foraging observation sessions per census point were conducted during each of the two breeding seasons (Robinson and Holmes 1982, Rodenhouse and Best 1994). Observations were taken within the cropped portions of the 50 m fixed-radius point count circles. Foraging data included identification of species observed to take invertebrate prey from crop vegetation. Birds were determined to be insect foragers if they perched on, or flew low over, crop vegetation while taking insect prey – at least one successful prey capture had to be observed for a bird to be designated as a forager. I then selected functional insectivores, or those species most likely to have an impact on insect pests in cropped areas, in the following manner – from among the species documented to be taking insects in cropped fields the ten species were picked that also occurred in the greatest densities in the cropped areas (from point counts). The factors (field and matrix characteristics; Table 2-1) associated with the highest recorded densities of the ten functional insectivores were then assessed in cropped fields that were sampled (see Data Analysis).

Data Analysis

Bird diversity

Because of my initial expectation that farm management would influence avian biodiversity, avifaunal differences between the organic and conventional farm sites sampled was broadly assessed, including species lists, comparisons of total species

counts with Breeding Bird Survey data and Audubon Society occurrence data from Alachua County (where most of the farms were located). Total species counts for each farm were determined by totaling the number of species detected on point counts, species noted inside cropped areas but outside the fixed radius during point counts, and species detected during search surveys (walk-abouts for 30 min).

In order to determine how field and matrix characteristics influenced bird species richness and density only point count data was used and analyzed in the following way. The number of individuals and species counted in each circle was averaged over all counts done in each circle in each year. Count data by crop versus field border portions of each count circle were also separated out. Thus, for each count circle the following 6 response variables were derived: mean number of species per count circle, mean number of species in the field border vegetation, mean number of species in crop vegetation; mean density of birds per count circle (standardized to # of birds / ha), mean density of birds / ha of field border, and mean density of birds / ha of crop. The three density variables and the three richness variables were submitted to two separate repeated measures multivariate analysis of variance (RM-MANOVA) with the following predictor variables: year (as the repeated measure), farm type, crop diversity, border type, and matrix type (Table 2-1).

Functional insectivory

Finally, to understand what farm-scale habitat features might influence insectivory in cropped fields a univariate repeated measures analysis of variance (RMANOVA) model was applied with the same predictor variables as above, and density of birds (ten functional insectivore species only) detected only in the crop half of count

circles as the response variable.

Results

Bird Species Richness on Organic versus Conventional Farms

In statistical models of factors influencing species richness, farm management (organic versus conventional) was never a significant predictor. However, on average, more bird species were observed on (and unique to) organic than conventionally managed farms (Figure 2-2, see Appendix A). A total of 64 different bird species were recorded in point count censuses during the first field season (1 May – 30 June 2000). Sixty species were observed in or near organic crops, 49 in or near conventional fields, 45 were common to both farm types, 4 were unique to conventional and 15 to organic systems. Seventy-four species were counted in 2001 (25 April – 30 June). Sixty-six of these species were observed in or near organic and 58 in or near conventionally managed fields, 52 species were common to both farm types, and 6 were unique to conventional systems, and 14 to organic systems (see Appendix A). Together, the species observed using farmscapes of North-central Florida represented 82 % of resident and migratory landbird species listed as breeders in Alachua County (where most of our samples were taken; Alachua Audubon Society 2003) and nearly all of those species noted in recent Breeding Bird Surveys along the two routes monitored in the same county (USGS 2001a, USGS 2001b; FFWCC 2003; Figure 2-2). I observed 24 listed species on organic farms (18 state listed, 6 federally listed), and 18 listed species on conventional farms (14 state, 4 federal; see Appendix A). Of the five farms with the most bird species, 3 were organic and 2 conventional. Finally, all 10 of the functional insectivore species (abundant insect-

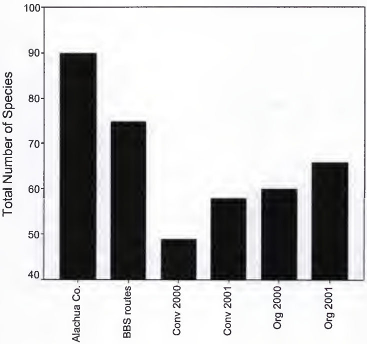


Figure 2-2. Number of landbird species known to breed in Alachua County, FL (Alachua County Audubon Society 2003) and species documented on the two Breeding Bird Survey routes (# 25013 and 25113; USGS 2001a, USGS b, Florida Fish and Wildlife Conservation Commission 2003) compared to the number of species observed in organic and conventionally managed farmlands of north-central Florida during the breeding seasons of 2000 and 2001 (1 May – 30 June, 25 April – 30 June, respectively).

eating species observed in cropped areas) were observed in both organic and conventional fields (see below).

Factors Influencing Bird Community Structure

Species richness

A RM-MANOVA model was constructed in the following way: year (2 levels) as the repeated measure; mean number of species per point, per crop half, and per border half of point count circles as response variables; farm type, crop diversity, field border type, adjacent matrix type as categorical predictors; all main effects and 2-way interactions were specified using Type III sum of squares. No within-subjects contrasts (year effects) were significant (at alpha = 0.05), and only field border type had a significant influence on species richness (per point; $F_{5,30} = 3.5$, $P = 0.013$, and field border half of the count circle; $F_{5,30} = 3.8$, $P = 0.009$; see Figure 2-3 caption for multiple comparison tests).

Bird density variation

Using the same RM-MANOVA model as above, with three different response variables (mean densities of birds per point, per crop, and per border half of count circles), again no effects of year were found, and only crop diversity significantly influenced bird densities (per point; $F_{1,30} = 7.4$, $P = 0.011$, and per crop half of the count circle; $F_{1,30} = 8.2$, $P = 0.008$); fields with more than one crop type had higher bird densities (Figure 2-4). All other factors and interaction terms were non-significant. I noted that the two most abundant species sampled were Northern Cardinal and Northern Mockingbird. Since these two species numerically dominated the data, and both are known to be edge and disturbance associated (Ehrlich et al. 1988, Derrickson and

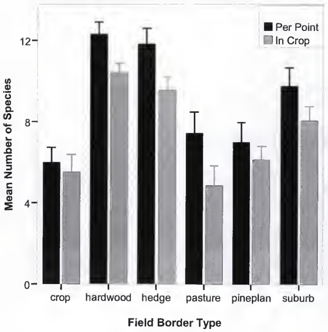


Figure 2-3. Mean number of species detected per point, and in crop half of point count circles (both years averaged). Error bars = 1 SE. Multiple comparisons tests (LSD) indicate the following: hardwood and hedge borders generated significantly more species per point than crop, pasture, or pine plantation borders ($P < 0.03$); hardwood borders generated more species in crops than all other border types except hedges ($P < 0.05$), and hedge borders generated more species in crops than pasture and pine plantation ($P < 0.03$).

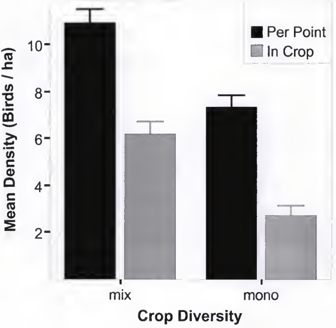


Figure 2-4. Mean densities of birds (all species) detected per point, and per crop half of point (years combined) in mono-cropped and poly-cropped fields. Error bars = 1 SE.

Breitwisch 1992, Halkin and Linville 1999), I decided to re-run this analysis without them to get insights about abundance variation of species with other kinds of habitat associations. The same RM-MANOVA model was re-applied and again found no effects of year but significant effects of crop diversity on densities of birds in crops ($F_{1,29} = 10.5$, $P = 0.003$; higher densities in mixed crops). Border vegetation type was also found to significantly affect densities per point ($F_{5,29} = 3.8$, $P = 0.01$) and in the crop ($F_{5,29} = 4.1$, $P = 0.006$; see Figure 2-5 caption for multiple comparison tests), and there was a significant interaction between adjacent matrix and field border vegetation types on bird densities in the crop ($F_{6,29} = 2.5$, $P = 0.044$; Figure 2-6). Given that I did not have all combinations of border and matrix types represented in my point count sampling, multiple comparisons could not be run on the interaction. However, of the combinations sampled, the greatest numbers of birds were observed in crops that were bordered by hardwood with adjacent pine plantation matrix, bordered by hedge with adjacent hardwood, pasture, or pine matrix, and in fields with pasture in both border and adjacent matrix (Figure 2-6).

Foraging activity in cropped fields: functional insectivory

After completing 2 h of foraging observations at each of the 60 census points each year, I focused further sampling in each year on the 30 points with the most foraging activity observed during the first two 1 h sessions (an additional 2 h of sampling at each of 30 points in each year for a total of 360 hours of foraging observations in cropped fields). Of the 49 species of birds observed in or near conventionally managed crops during the 2000 breeding season, 14 species (29%) foraged in crop vegetation, and 23 of 60 (38%) species on organic farms foraged in crop vegetation (see Appendix A). In 2001, 20 of 58 (35%) species on conventional and 36 of 66 species (55%) on organic farms actively

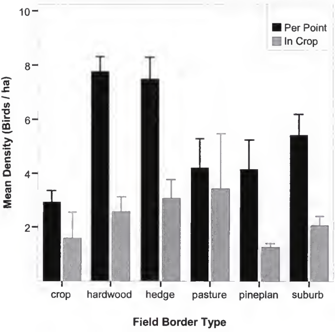


Figure 2-5. Excluding Northern Cardinals and Northern Mockingbirds, mean densities of all birds per point, and per crop half of point count circles, by field border type (years combined). Error bars = 1 SE. Multiple comparisons tests (LSD) revealed the following ($P < 0.03$): hardwood borders generated higher densities per point than all types except hedge, and hedge generated higher densities per point than crop, pasture and pine plantation. No multiple comparisons among border types for bird densities in crop half of count circles were significant (although the main effect was).

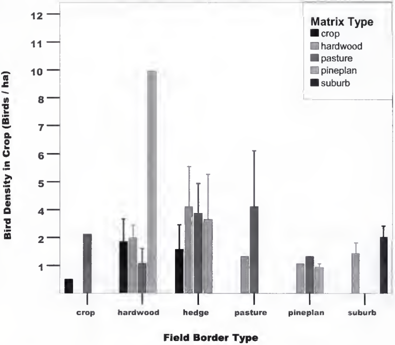


Figure 2-6. Excluding Northern Cardinals and Northern Mockingbirds, mean bird densities in crops given different combinations of field border vegetation type and adjacent matrix vegetation type. Error bars = 1 SE.

foraged in cropped areas. In both seasons I noted that foraging activity was most common in cropped areas with perching structures from which birds could survey for potential food items. Densities of the ten functional insectivore species were significantly greater in the crop half of census points that contained numerous perching structures ($t = 6.13$, $p < 0.001$, $N = 60$). This was true whether the perch was manmade (e.g. an elevated sprinkler head) or vegetative (e.g. sunflower or corn stalks) regardless of farm management type.

Of the ten functional insectivore species identified, only 4 are usually classified as insectivores, one as a carnivore, and 5 of the ten species are normally considered omnivores (De Graaf et al. 1985, see Appendix A), although all are known to be insectivorous during the breeding season (Beal et al. 1941, Martin et al. 1951, Ehrlich et al. 1988). Individuals of these species were observed to capture insects from crop vegetation and either eat them immediately or carry them into adjacent matrix, presumably to feed young. The two most abundant of the functional insectivores (Northern Cardinals and Northern Mockingbirds; Figure 2-7) were also the most abundant species overall (see above). Using a RM-ANOVA model (using the same predictor variables and model structure as in the community structure analysis, above), but only one response variable (mean densities of these ten species in cropped half of count circles), no effect of year was found, and the only significant main effect was crop diversity – mixed crop areas had more functional insectivores than monocrops ($F_{1,29} = 4.2$, $P = 0.051$; Figure 2-8).

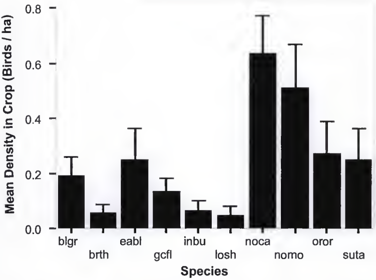


Figure 2-7. Mean densities of the ten functional insectivores observed in crop half of census points. Species codes: blgr = Blue Grosbeak, brth = Brown Thrasher, eabl = Eastern Bluebird, gcfl = Great Crested Flycatcher, inbu = Indigo Bunting, losh = Loggerhead Shrike, noca = Northern Cardinal, nomo = Northern Mockingbird, oror = Orchard Oriole, suta = Summer Tanager. Error bars = 1 SE.

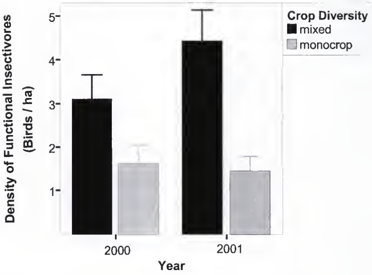


Figure 2-8. Mean density of ten functional insectivores in fields with 1 (mono) or more than 1 (mixed) type of crop planted, by year. Error bars = 1 SE.

Discussion

Avian Diversity on North-central Florida Farmlands

Avian species richness at census points (whole point and border half of count circle) was strongly influenced by field border types, with hardwood forest and hedge borders harboring the greatest diversity (Figure 2-3). This finding confirms the general pattern that structurally complex windbreaks, hedgerows and field borders support more complex farmland bird communities than conventional 'clean-farming' practices that suppress non-crop vegetation (e.g. Osborne 1984, Green et al. 1994, Parish et al. 1994 & 1995, Chamberlain and Wilson 2000). Data analyses did not reveal any other field-scale features or matrix types causing significant variation in the number of bird species visiting the crop half of our point count circles. This is likely to be because the majority of species attracted to habitats in fragmented farmscapes also utilize fields (see Appendix A) and those few that do not utilize open fields are those that rarely come to the ground (e.g., great horned owl, cedar waxwing, red-eyed vireo) or that have behavioral limitations on entering open areas (e.g., Sieving et al. 1996).

Densities (species combined) of birds, however, varied significantly (among point counts and in crop half of point counts) with border and matrix vegetation type and with crop type. With or without Northern Cardinals and Northern Mockingbirds included in the analysis, fields with mixed crops attracted greater numbers of individuals than mono-crop fields (Figure 2-4), and when the two common generalist species were removed, border and matrix habitat type also significantly affected bird densities in the crops and in point count circles (Figure 2-5). Thus, removal of mockingbirds and cardinals was important because as habitat generalists, their numerical dominance in our data could

have masked the responses of most species to the farmscape features we considered (see Best et al. 1995). Hardwood and hedge field borders increased bird densities per point (Figure 2-5; as they did number of species), and although it appears that hardwoods, hedge, and pasture generated the highest densities in crops (Figure 2-5), the lack of significant contrasts was probably due to: 1) the low densities of birds once the two most abundant were removed and, 2) the significant interactions between border type and adjacent matrix type.

Findings of this study support tentative generalizations emerging from larger scale (landscape) analyses of bird distributions that have found blocks of hardwoods or natural grassland adjacent to cropped areas tend to generate the highest bird diversity on farmlands (Best et al. 1995 and 2001, Kirk et al. 2001), and that total area and juxtaposition of vegetative cover types comprising recognizable farmscape elements (field borders, windbreaks, etc.) largely determine bird densities in agroecosystems (Freemark et al. 1993, Rodenhouse et al. 1993). Thus, this study emphasizes that, both, the dominant vegetative communities in landscapes where farms and farm fields are imbedded and the spatial configuration of habitat on farms determine bird species diversity on farms. Farmers seeking to manage bird diversity do not have control over landscape context (once a farm is purchased). But these results suggest that schemes to design on-farm habitats (crops, field borders, and location of planted fields with respect to adjacent matrix types) to influence bird diversity could be effective, very flexible, and accommodate different classes of birds (i.e. woodland, grassland, edge, generalist species) and, therefore, be excellent tools for avian conservation in agroecosystems (see below).

Bird Diversity on Organic versus Conventional Farms of North-central Florida

In apparent contradiction with other studies in North America (Freemark and Kirk 2001, Beecher et al. 2002) and Europe (Christensen et al. 1996, Chamberlain et al. 1999) that documented significantly greater bird diversity associated with organic farming practices, I detected only slight enrichment of bird diversity in organic versus conventional farming systems of North-central Florida. In fact, most species that could be expected in North-central Florida during the breeding season were observed utilizing the farmscapes I studied, regardless of farm management (Figure 2-2). This contradiction derives from differences in cropping practices on the farms studied by others, and in the scale at which studies were conducted. In the other studies, birds were surveyed primarily in farms with mono-cropped fields – mixed crops were uncommon and variables similar to our 'crop type' predictor were not incorporated into analyses. As an *a priori* variable in analysis models, crop diversity proved to be a very strong predictor of bird density. Since both conventional and organic farmers in my sample employed mixed and mono crops, differences in bird occurrence generated by chemical applications may have been insignificant by comparison. Moreover, both organic and conventional farms in North-central Florida are relatively small (10 out of 16 were less than 10 ha) compared to farms used in other studies that spanned a considerable size range (from a minimum of 10 – 40 ha to much larger). North-central Florida is still largely forested, and because farms were relatively small, most farm fields were close (or adjacent) to significant areas of hardwood forest – the habitat that generated the highest farm-bird diversity in this study. The current landscape is likely to represent a 'patch mosaic' of diverse habitat types long recognized as essential for the maintenance of bird (and other) species on

farmlands (birds; O'Conner and Boone 1992, Best et al. 1995: plants; Freemark et al. 2002: moths; Ricketts et al. 2001: ants; Perfecto and Vandermeer 2002). Thus, I speculate that in farming regions with larger farms (and larger farm fields), where sources of birds are more distant and mixed cropping is less frequent, organic farm practices may be more important in determining species diversity than in landscapes with small-scale farms and a diverse habitat mosaic.

Functional Insectivory in Cropped Fields

I found that birds were willing to utilize cropped fields to forage at most census points regardless of crop type or management. However, in both years, fields planted with polycultures attracted the greatest densities of the ten functional insectivore species, compared to monocropped fields, regardless of other factors (Figure 2-8). The most attractive fields in this study had vegetable and cut flower intercrops, followed by multiple vegetable crops, and monocropped systems had the fewest birds; monocropped watermelon was the least attractive crop. These results are similar to those of Robbins et al. (1992), Rodenhouse and Best (1994), and Stallman and Best (1996) where avian diversity, abundance, and foraging activity were strongly associated with increased structural complexity of vegetation in cropped fields. In general, birds can rapidly assess within-habitat variation in food availability (Fretwell and Lucus 1970, Hutto 1985) and will quickly recruit to feed in food-rich patches. Since insect species richness and diversity increase with vegetation diversity in cropped fields (Elliott et al. 1998) and are greater in polyculture verses monoculture systems (reviewed by Andow 1991), the increased functional insectivore foraging activity I observed in mixed crops verses monocultures was probably driven by variation in arthropod prey resources (though I did

not quantify this). Because organic fields tend to support greater arthropod diversity and density (Dritschillo and Wanner 1980, Hald and Reddersen 1990, Brooks et al. 1995, O'Leske et al. 1997, Feber et al. 1997 & 1998), and because high bird diversity in organic fields has been linked to richer arthropod foods (Brea et al. 1988), the lack of a significant difference in bird diversity between organic and convention fields in this study suggests that polyculture cropping in conventional systems also results in an overall greater arthropod diversity and abundance (Paoletti et al. 1992, Stary and Pike 1999).

One important determination I made during this study is that without watching what birds eat when they are in fields, farmers and researchers alike may mistake the roles that different species play. Because a few birds can be significant pests in agroecosystems, eating sprouted plants, seed crops, and ripening fruits (Weed and Dearborn 1935, Beal et al. 1941, Dolbeer 1990, Rodenhouse et al. 1993), this role is often the first one ascribed to any birds observed in cropped areas. In this study I observed abundant insectivory and only isolated instances of fruit damage (by mockingbirds on strawberries) by birds in my study fields. But while many of the species observed to take insects are normally classified as insectivores, several of the functional insectivores are not. The Northern Cardinal is usually classified as an omnivore (De Graaf et al. 1985) and popularly known as a seed-eater because it frequents backyard bird feeders. Yet the cardinal was the most abundant functional insectivore in this study. They made longer foraging bouts and took more insects than other species, and either immediately consumed them or carried them into nearby field margins (presumably to feed young). Two other species typically classified as omnivores (or popularly thought of as granivores), blue grosbeaks and indigo buntings, were also among the functional

insectivores (top ten most common species in cropped fields taking insect prey; see Appendix A, Figure 2-7) and caused no crop damage during our observations. Clearly, these species are omnivores when the diet is summarized over an entire year. But because many omnivores and primarily granivorous species become highly insectivorous during the breeding season to support their energetic needs and those of their nestlings (Beal et al. 1941, Martin et al. 1951, Ehrlich et al. 1988), I advocate the utility of 'functional insectivore' in the context of farm birds. If the seasonality of bird diets is emphasized, then farmers and conservationists alike can make more careful, and more accurate, assessments of the potential positive and negative interactions birds can have with cropping systems.

In conclusion, I found a large number of insectivorous bird species utilize cropped fields of North-central Florida (see Appendix A), and direct observations during foraging bouts indicated that most of these species were actively capturing insect prey from crop vegetation. Insectivorous birds exhibit numerical and functional responses to insect outbreaks in North American forest systems, potentially decreasing pest outbreak frequency and severity (Holling 1988, Dahlston et al. 1990, Holmes 1990). This work supports the general assessment that the ecological role of birds, as insect predators in agroecosystems, is likely to realize enhanced production and economic values to farmers. Moreover this work, in light of the current dearth of studies attempting to document economic and production benefits of natural pest control agents, begs for further investigation of avian insectivory as a component of pest management schemes that are consistent with ecologically sound agriculture (Jackson 1979, McFarlane 1986 and Kirk et al. 1996).

Conservation Implications

Increased awareness of the functional role that insectivorous species may have in cropping systems could further encourage producers to engage in avian conservation efforts on their lands. Recent surveys of farmers in North-central Florida indicated they were supportive of increasing populations of certain bird species if it would benefit their production efforts (i.e. insectivorous birds that may eat insect crop pests; Jacobson et al. 2003). Encouragingly, an overwhelming majority of farmers surveyed believed birds could help lower insect populations on their farms (91%). Most farmers also indicated that they would like to attract such birds to their farms (85%), and over a third of these farmers were already engaged in attracting birds to their farms (Jacobson et al. 2003). Additionally, since farmers in Florida have expressed great interest in conservation of birds if they can aid in control of insect pests (without causing crop damage; Jacobson et al. 2003), the potential for integrating bird conservation with farm production is encouraging, particularly if more research is devoted to assessing realized benefits to farmers. This work suggests that functional insectivory in fields can be encouraged at the farm scale (by land-owners) by planting polycultures in fields adjacent to blocks (matrix) of hardwood and pine forest with structurally complex field borders (hardwood, hedge) between the matrix and the crop. It was also observed that insect eating birds heavily utilized elevated perch structures (irrigation pipes, sprinkler heads, wire fence posts, trellises, and natural structures such as sunflowers, cornstalks, bushes, and trees). Though I did not characterize these effects, perches to enhance bird activity in disturbed areas appears to be effective in many systems (Holl 1998). My next steps are to pursue

an understanding of economic benefits of on-farm manipulations of functional insectivores.

While farmers cannot readily manipulate the relative abundance of land cover and land use at the landscape scale surrounding their farms, it is quite clear that farms in landscapes with greater proportions of their original native habitats will be able to attract more birds, in part because larger pools of species and individuals are supported in such landscapes. It is also apparent that such landscapes generate complex mosaics at the farm scale, unlike regions with large (corporate) conventional farming operations adjacent to one another. Because most recent studies of bird diversity on farms in the U.S. have occurred in expansive conventional systems of the Midwest (see Best et al. 1995, Best et al. 1997, Beecher et al. 2002) and California (see Elphick and Oring 1998, Bird et al. 2000), where there is little habitat (and impoverished avifaunas that often cause crop damage), and because such conventional corporate farms comprise most acreage in agricultural use, the current view of integrating birds and agriculture is somewhat pessimistic (Peterjohn 2003). Numerically, most ***farms*** in the US are small to medium sized traditional operations occurring in landscapes with a mosaic of crop and non-crop habitat elements (ERS-USDA 2003), like the farms in this study. A recent national study found the average small farm devotes 17% of its land to forest patches compared to 5% on large farms, and allocates nearly twice the acreage to soil improvement efforts such as cover crops (D'Souza and Ikerd 1996). Additionally, non-cropped acreage or acreage set aside for conservation purposes is substantial among small farms in the U.S. For example small family farm operators controlled 85% of acres enrolled in the Conservation Reserve Program as of 1998 (USDA 2001b). Given that many of the small

farms surveyed in North-central Florida appear to provide suitable habitat for a diversity of species, and that these farmers' attitudes toward avian conservation are positive, I argue that the prevailing negative view of agriculture as a partner in biodiversity conservation is counter-productive. Large-scale conventional farming operations that dominate large regions and comprise the majority of farmed areas in the US are, indeed, devastating to birds and native biodiversity in general. But studies, including mine, indicate that ***most farms*** (the smaller operations in diverse landscapes) already support significant avian (and other) biodiversity, in part, because ***most farmers*** are open to fostering such conservation goals. Therefore, I am encouraged that the potential to alter ***agriculture*** in positive ways is tremendous. Policies are in place that provide monetary and other incentives (i.e. 2002 Farm Bill conservation programs), and ***most*** stakeholders are apparently open to possibilities (Jacobson et al. 2003), and the kind of research needed to establish an economic basis for more ecologically sound agriculture is known (McNeely and Scheer 2003).

CHAPTER 3
INTERCROPPING WITH SUNFLOWERS TO CREATE LOCAL REFUGIA FOR AVIAN PREDATORS OF ARTHROPOD PESTS

Introduction

Innovative crop protection, through enhancement of predator-prey relationships characteristic of natural systems, has a pivotal role to play in the evolution of agriculture towards environmentally sustainable systems (Atkinson and McKinlay 1997). Methodologies that promote pest insect predators (e.g., birds, bats, wasps, beetles) on farms can augment both non-chemical crop protection and conservation of biological diversity in agricultural landscapes. Although the value of native insectivorous animals as predators in agroecosystems was once widely recognized and promoted by scientists and farmers, research on potentially beneficial species inhabiting agroecosystems was largely abandoned in 20th Century North America due to the pervasive use of pesticides and related technologies. As sectors of the agricultural industry explore lower input systems (e.g., organic farming, natural systems agriculture; Colby 1990) to reduce destructive impacts on human health (www.epa.gov/pesticides/citizens/riskassess.htm) and ecosystem functions (Altieri 1994), research focused on designing farming systems that emulate more complex ecosystems is urgently needed. Efficient and sustainable agro-ecosystems will support ecosystem functions and species composition that reflect local biotic and abiotic conditions (Soule and Piper 1992, McNeely and Scherr 2003). Thus, research

on sustainable and ecologically sophisticated agriculture should develop designs appropriate for local conditions and sets of species, in addition to general principles of agroecosystem function and management (Lewis et al. 1997).

Biological control by natural enemies has been the most successful and promising alternative to unilateral reliance on chemical pesticides (Hoy 1992, Zalom et al. 1992), and is considered to be the 'backbone' of integrated pest management schemes (Rosen et al. 1996). The economic value of biological control methods included in integrated pest management (IPM) programs may be considerable over long time periods. For example, a study of citrus production in the San Joaquin Valley of California indicated substantial savings of pesticide and energy costs could be realized by growers utilizing IPM methodologies (Flint 1992). Biological control methods that promote native pest insect predators for non-chemical crop protection, by their nature, also contribute to conservation of biological diversity in agricultural landscapes (The Soil Association 2000).

Habitat Management for Predators in Agroecosystems

Habitat management to enhance biological control refers to the establishment of environmental conditions amenable to natural enemies that increase and sustain their populations and improve their effectiveness in controlling pests (Pickett and Bugg 1998). Population processes such as colonization / dispersal and foraging movements of predators can be influenced by habitat modifications (Helenius 1998). On farms, such dynamics of natural enemy populations can be altered through management of within-field strips, cover crops, field margins, hedgerows, fencerows, windbreaks, irrigation and drainage ditches, and roadside margins. For example,

Nentwig (1998) found that sown weed strips within cropped areas increased arthropod enemy abundance and activity in crops, via greater effective dispersal into the interior of expansive fields. Moreover, predation rates on pest species were higher near the sown strips. Others have recognized the potential importance of predator refugia within farmed areas for pest control and call for better understanding of the mechanisms underlying refugium design and function for managing natural enemies (Schoenig et al. 1998, Wratten et al. 1998).

Clearly, agroecological infrastructure (e.g., the landscape context and within-field structure of cropped areas) affects the maintenance and activity of predators at the scale of individual fields, and the conservation of predator diversity (richness and abundance) requires consideration of both favorable and unfavorable habitat aspects when designing predator-friendly agroecosystems (Booij and Noorlander 1992, Wratten et al. 1998). For example, studies of abundances and foraging activities of insectivorous birds in cropped systems (reviewed by Kirk et al. 1996) suggest that bird use of crops for foraging depends not only on food abundance, but also upon vegetation cover and microclimate in the field (Rodenhouse and Best 1994) and upon habitat composition in the surrounding landscape (see Chapter 2).

Objectives

This study investigates the effect of within-field habitat structure upon the abundance and foraging activity of insectivorous birds in cropping systems where all features are under the direct control of farmers. The occurrence, densities, and foraging activities of insectivorous birds in cropped fields are significantly higher in those having the greatest diversity of vegetation (polycultures vs. monocultures; see

Chapter 2). Therefore, the overall objective of this study was to examine the effect of sunflowers (*Helianthus annuus*) within cropped fields as refugia for birds. I tested the hypothesis that sunflower rows included in a cropping system would increase the occurrence, density, and foraging activity of insectivorous birds in cropped fields. Additionally, I varied the density of sunflower rows per unit-area to determine its influence on bird behavior and distribution in cropped fields. I conducted observational assessments of foraging activity budgets of insectivorous bird species utilizing cropped fields with sunflower rows compared to control plots. Using visual observations I attempted to verify if birds were consuming economically important pest insects. Forced regurgitation gut samples were collected from a few birds captured in mist nets after they foraged in crop vegetation to aid in this verification. Insects found within regurgitate samples were identified to order and family.

The addition of sunflowers to attract beneficial insects into cropping systems has been described in several extension fact sheets (Univ. of Florida Extension Circular 563, Univ. of Rhode Island Landscape Horticulture Factsheet, Univ. of Maine Coop Extension Bulletin # 7150) and gardening publications (Long 1993, Starcher 1995, Turton 1998). However, one concern with adding non-crop vegetation strips within cropped fields is that this treatment may attract and increase the abundance of pest insects to the crops (Bugg and Pickett 1998). Therefore, I also performed a limited survey of the insect fauna found in sunflower treatment plots to establish a partial listing and the relative occurrences of both beneficial and pest arthropods found on sunflower and nearby crop vegetation (sensu Henn et al. 1997 and the UF Coop. Ext. Service Insect Identification Sheets SPSET 5 1997).

Methods

Research Site Selection

Growers were identified in North-central Florida during the fall of 2001 and permission was obtained to conduct research activities on their properties. All participating farms were under certified organic management as designated by the Florida Organic Growers Association (Florida Certified Organic Growers and Consumers, Inc., PO Box 12311 Gainesville, FL 32604) and most are now USDA Organic certified.

Experimental Design

Four organic growers were asked to incorporate rows of multi-branched open-pollinating varieties of sunflowers into their cropped acreage at the earliest planting dates during their spring – summer growing seasons 2002 and 2003. These multi-branched sunflowers have been observed to provide foraging, roosting, and even nesting micro-habitat for many species of insectivorous birds in two organic farms that already incorporate them extensively for cut flower production (Jones unpublished data). Vegetable crops grown in the experimental blocks chosen for the study included polycultures of kale, collard greens, yellow and zucchini squash, tomatoes, green beans, cucumbers, and sweet corn. Only two of the farm sites had entire fields dedicated to a single crop type (sweet corn).

A total of 18, 4-hectare blocks were available for the study 8 of which received sunflower row treatment while the other 10 served as controls within the farm sites. This unbalanced arrangement of 8 treatment and 10 control blocks was necessary to ensure that each farm contained at least 1 control and treatment block, to

pair crop types in treatment and control blocks as much as possible, and to allow the incorporation of sunflower rows into blocks in such a way as to minimize their impact on each farmer's production regime. Treatment blocks were divided among farms that ranged in size from 8 ha to 80 ha in size with 2 blocks in the smallest farm, 4 blocks in each of 2 farms that were 20 ha in size, and 8 blocks in the largest farm. A randomized block design was incorporated into the 4-hectare plots with sunflower row treatments at varying densities of 0, 1, or 2 rows per 0.4 ha. All sunflower rows consisted of 1m-wide rows of plants at a density of 9 plants per square meter and were interspersed between, and parallel with, production rows (Figure 3-1). In all blocks that had sunflower rows placed in them the rows were centered in roughly rectangular fields, planted in strips that would not otherwise have had crop vegetation, and were approximately 100 m in length (Figure 3-2).

Sunflower rows were maintained throughout the spring growing season as other crops were planted, harvested, and rotated through each farm's production area. Treatment blocks were assigned different treatments during the second field season (either 1, 2 or no rows/0.4 ha of sunflowers) to control for differences in the border habitat types that were adjacent to each treatment block. This was important since border habitat types significantly affect the numbers of birds available to venture into cropped fields. Avian occurrence and abundance in field borders varied significantly from site to site being greatly influenced by the vegetation composition of the field border (see Chapter 2).

Figure 3-1. Multi-branching sunflower varieties were planted at 1 or 2 rows per 0.4 ha between vegetable rows to attract birds and beneficial insects into cropped fields. A row of sunflowers is shown here planted in a non-production strip containing irrigation sprinklers between rows of tomatoes.

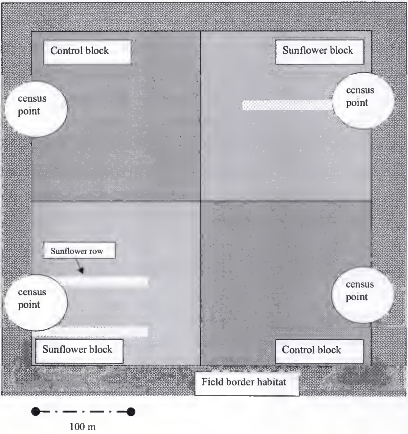


Figure 3-2. Typical layout of treatment and control blocks at a 20 ha farm site. A randomized block design was incorporated into the 4-hectare plots with sunflower row treatments at varying densities of 0, 1, or 2 rows per 0.4 ha. All sunflower rows consisted of 1m-wide rows of plants at a density of 9 plants per square meter and were interspersed between, and parallel with, production rows. In all blocks that had sunflower rows placed in them the rows were centered in roughly rectangular fields, planted in strips that would not otherwise have had crop vegetation, and were approximately 100 m in length.

Bird Sampling

Birds were censused and their foraging activities quantified throughout the 2 growing periods from 1 April – 15 June 2002 and 2003. Birds were censused 6 times in each treatment and control block utilizing standard point count methods (Bibby et al. 1992) modified as described by Freemark and Rogers (1995) for censusing in croplands. All census points were located at least 200 m from each other when occurring within the same farm management unit. Point counts were conducted between dawn and 1000 EST on fair weather days. All birds seen or heard within a 50 m fixed-radius from each census point during a ten-minute period were recorded. Observations began 2-3 minutes after I arrived at each point count station. Birds flying over sample areas were excluded, except swallows or martins if they were feeding on aerial invertebrates directly over crop vegetation (see Boutin et al. 1999). Utilizing mapping data sheets (marking exact locations of individuals and their movements) minimized duplicate records. Both species numbers and bird densities were averaged across samples at each point. Univariate analyses were performed to compare bird densities within the treatment and control blocks to determine sunflower row treatment effects upon bird response variables among experimental plots for the study (Zar 1999).

Point count circles used to assess bird species occurrence and density were located on the edges of fields centered to the ends (1 sunflower row plots) or between (2 sunflower row plots) sunflower rows in treatment blocks, ½ in the field and ½ in the field border vegetation (Figure 3-2). For comparisons among treatments and control blocks, only birds detected in the crop half of count circles were used in

assessing species occurrence and density. Count circle radii extended ½ the length of the sunflower rows, and were therefore sufficient to detect sunflower effects on birds. Half of each count circle was located in the field border vegetation for two reasons. First, standing in the border provided some cover to reduce the conspicuousness of the observer (and minimize effects on bird behavior in the crop). Second, all census points in this study were censused in the 2 years previous to this study and those data were used to assess variation in bird abundances in cropped field blocks among years and treatments.

Foraging Surveys

Observations of foraging behavior were made during six, 1-hour scan sampling sessions (Martin and Bateson 1993) at each treatment plot spread over the study period. Avian species observed to forage in crop vegetation and the time spent in foraging bouts were noted. Birds were considered foraging if they were observed to be making their way through or on crop vegetation and actively scanning or probing that vegetation for prey items (as opposed to being perched and resting, singing, or grooming etc.). Any successful capture of an insect prey item was noted and an attempt was made to visually identify those insects being consumed by foraging birds. Use of sunflower plants by foraging species was described. The degree that inclusion of sunflower rows increased foraging activity in surrounding crop vegetation was determined by univariate analysis of variance comparing differences in mean numbers of birds and duration of foraging bouts among treatment blocks. Regression analysis was used to examine the relationship between foraging activity and growth of sunflower plants through each growing season (Zar 1999).

Gut Content Surveys

An attempt was made to identify insects eaten by insectivorous birds within the test plots through gut content analysis. Birds were captured directly after foraging in crop vegetation utilizing mist-netting techniques within treatment plots. A partial sample of each bird's stomach contents was collected via a non-lethal forced regurgitation (Prys-Jones et al. 1974). After capture, birds were administered an oral emetic consisting of a $0.1 cm^3$ of 1% solution of antimony potassium tartrate per 10 g of body mass and placed in a darkened holding cage lined with wax paper. Within 2 – 3 minutes, most birds regurgitated pellets of partially digested insects that were then collected and preserved in alcohol for identification. Birds were then released at point of capture after a short rest period and an examination for any signs of stress. Samples obtained in this way are highly correlated with total crop and stomach contents of collected birds (Rosenburg and Cooper 1990).

Insect Surveys

Insects were sampled a minimum of 3 times in 10 randomly chosen 1 m^2 quadrats within sunflower rows and in 10 randomly chosen locations in crop vegetation a minimum of 10 m distant from the sunflower rows within treatment blocks during the growing season 2002. During 2003 insects were again sampled a minimum of 3 times in 10 randomly chosen 1 m^2 quadrats within sunflower rows, 10 quadrats in crop vegetation at 1 m, and 10 quadrats at 10 m distant from the sunflower rows. Insects were sampled utilizing a standard scouting technique in each quadrat counting the numbers of individuals found per 1 m^2 of crop vegetation (after Morris 1960, Southwood 1978). Insects observed were identified to family level and

relative abundances noted. Using Henn et al. (1997) and the UF Coop. Ext. Service Insect Identification Sheets SPSET 5 (1997), I classified insects as "beneficials" or as crop pests. Then, I compared the occurrence and number of individuals per m^2 beneficial and pest insects found upon sunflower plants and crop vegetation (at 2 distances away from sunflowers in year 2) during the two growing periods (Zar 1999).

Results

Bird Species Occurrence and Densities

A total of 68 species were observed utilizing cropped areas of the treatment and control blocks or their bordering habitats (within 50 m of field edges; see Appendix B). Of these 68 species observed within the blocks, 62 species (91%) were observed in the border habitat while 49 species (72%) were observed in the cropped areas themselves; 5 of which were only observed in the cropped fields. Mean densities of birds occurring in the cropped areas of the treatment and control blocks varied significantly from year to year during the study and from the two years (2000 and 2001) previous to the study (2.9 birds/ha in 2003, 3.3 birds/ha in 2002, 4.3 birds/ha in 2001, and 1.8 birds/ha in 2000; $F_{3, 324} = 2.74$, $p = 0.04$). During the study cropped areas with sunflower treatments of one row and two rows per 0.4 ha exhibited significantly greater mean densities of birds than did control plots (3.5 ± 3.5, 5.8 ± 4.5, and 0.9 ± 1.8 birds/ha respectively; $F_{2,200} = 43.33$, $p < 0.001$). This difference was apparent with the addition of just a single row of sunflowers per 0.4 ha (Figure 3-3). Differences in bird densities between treatment and control blocks were greatest

in 2003 (2-way ANOVA Year x treatment $F_{2,200} = 4.41$, $p = 0.013$) during which blocks having 2 sunflower rows per 0.4 ha exhibited a 206% greater mean density of birds than did 1 row and a 1500% greater mean density of birds than did control plots (Figure 3-3). Mean bird densities occurring in cropped areas were not significantly different among these same blocks in the two years previous to this study (2000: $F_{2,53} = .843$, $p = 0.436$; 2001: $F_{2,53} = 1.41$, $p = 0.254$).

Foraging Behavior

Foraging observations during the 2 growing seasons indicated that the presence of sunflower rows significantly increased the presence and activity of insectivorous birds in vegetable or row-crops compared to control blocks. Mean number of individual birds foraging per hour in cropped areas was significantly greater in those blocks with sunflower rows versus control blocks, 0.7 ± 0.1 and 1.7 ± 0.1 individuals per hour respectively ($F_{1,196} = 59.84$, $p < 0.001$; Figure 3-4). Mean foraging activity per hour in cropped areas was also significantly greater in those blocks with sunflower rows versus controls, $0.06 \pm .01$ hr and $0.24 \pm .02$ hr respectively ($F_{1,196} = 51.93$, $p < 0.001$; Figure 3-5). This difference in foraging activity was consistent each year as treatment plots were rotated among the 18 experimental plots. Mean time birds spent foraging in crop vegetation significantly increased over the course of each growing season as both sunflowers and crop vegetation matured ($F_{1,} = 9.13$, $p = 0.003$). Birds were found to be attracted to and utilize sunflower plants as perches by the time they were 0.6 m tall. As sunflowers increased in stature through the growing season, birds were observed to increasingly utilize sunflower plants as cover and perch sites from which they would forage into crop vegetation (Figure 3-6).

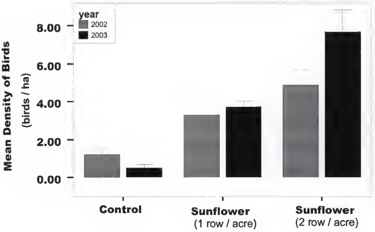


Figure 3-3. Sunflower treatment plots exhibited significantly greater mean densities of birds in the cropped fields than control plots during both spring growing seasons ($F_{2,200} = 43.33$, $p < 0.001$), and especially in 2003 (2-way ANOVA Year x treatment $F_{2,200} = 4.41$, $p = 0.013$). This difference was apparent with the addition of just a single row of sunflowers per 0.4 ha increasing mean density nearly 4 times that of control plots. Error bars = 1 SE.

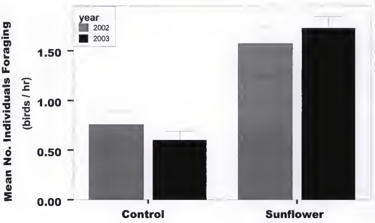


Figure 3-4. Mean number of individual birds foraging in cropped areas was significantly greater in those plots with sunflower treatments in both growing seasons 2002 and 2003 ($F_{1,196} = 59.84$, $p < 0.001$). Error bars = 1 SE.

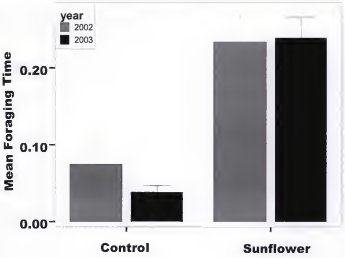


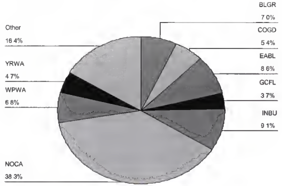
Figure 3-5. Mean foraging time (proportion of 1 hour observation session) in cropped areas was significantly greater in those plots with sunflower treatments in both growing seasons 2002 and 2003 ($F_{1,196} = 51.93$, $p < 0.001$). Error bars = 1 SE.

Figure 3-6. As sunflowers increased in stature, birds were observed to increasingly utilize sunflower plants as cover and perch sites from which they would forage into crop vegetation. An Eastern Kingbird (*Tyrannus tyrannus*) surveys crop vegetation from a sunflower perch looking for prey.

During the 216 hours of foraging observations made during the study period a total of 428 foraging bouts were observed. The species most often observed to forage in crops for insects included 2 resident species Northern Cardinals (*Cardinalis cardinalis*) and Eastern Bluebirds (*Sialia sialis*), and two migrants, Blue Grosbeaks (*Guiraca caerulea*), and Indigo Buntings (*Passerina cyanea*)(see Appendix B). These four species accounted for 63% of the foraging bouts observed and 65% of the time birds were observed to forage in the treatment and control blocks during the study (Figure 3-7). Northern Cardinals were the most prevalent foragers throughout each growing season accounting for more than 1/3 of the foraging bouts observed. Eastern Bluebirds were also common foragers accounting for 8.6% of the foraging bouts observed. Blue Grosbeaks and Indigo Buntings became common foragers (7% and 9% of foraging bouts observed respectively) as they returned from wintering grounds several weeks into the two growing seasons. Small flocks of species that winter in North-central Florida such as Western Palm Warblers (*Dendroica palmarum*) and Yellow-rumped Warblers (*Dendroica coronata*) were observed foraging in cropped areas during the first few weeks of each growing season.

In approximately 10% of the foraging bouts I was able to identify an insect prey item that had been captured. Two of the most common prey identified were lepidopteran larvae and grasshoppers. Inspections of crop vegetation after bouts, in spots where birds had foraged, allowed further confirmation of likely prey species being consumed. Insects most prevalent in inspected foraging sites included Green Stink Bugs (*Acrosternum hilare*), Imported Cabbageworm (*Pieris rapae* - Linnaeus), and numerous Dipterans (Figure 3-8).

a. Foraging bouts



b. Foraging time

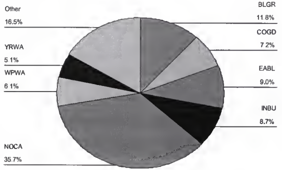


Figure 3-7. Species-specific proportion of foraging bouts (a.) and time spent foraging per hour (b.) of birds observed during 216 hours of observation in sunflower and control blocks during the 2002 and 2003 spring growing seasons. Northern Cardinals (*Cardinalis cardinalis*), Eastern Bluebirds (*Sialia sialis*), Blue Grosbeaks (*Guiraca caerulea*), and Indigo Buntings (*Passerina cyanea*) accounted for 63% of the foraging bouts observed and 65% of the time birds were observed to forage in the treatment and control blocks during the study. See Appendix B for complete list of those species observed foraging in crops.

Figure 3-8. Birds foraging in crop vegetation were observed to consume numerous lepidopteran larvae as well as grasshoppers and beetles. Insects consumed by birds included Green Stink Bugs (*Acrosternum hilare*), Imported Cabbageworm (*Pieris rapae* - Linnaeus), and numerous Dipterans.

Insects were taken directly from crop vegetation and either consumed on the spot or carried into nearby field border habitat (presumably to be consumed there or to feed to young). A total of 20 birds observed to forage for insects in crop vegetation (10 Northern Cardinals, 3 Blue Grosbeaks, 6 Indigo Buntings, and 1 Summer Tanager) were captured immediately after foraging. Regurgitated gut samples obtained from 12 of these captured birds confirmed that economically important pest insects were consumed such as leaf-chewing caterpillars and grasshoppers (Figures 3-9). Remains of beneficial insects were not evident in these gut samples.

Beneficial and Pest Insect Occurrence

Beneficial insects were attracted to sunflower plants by the time they reached 0.15 m in height. Beneficial insects observed on sunflowers and nearby crop vegetation (within 1m of sunflowers) included arthropod predators, parasitic wasps, and important pollinators representing 30 different families (Appendix C). The most commonly occurring beneficial insects observed on sunflowers were Big-eyed Bugs (*Geocoris* ssp.), Honey Bees (*Apis mellifera*), Green Lynx Spiders (*Peucetia viridans*), Ants (Formicidae), and Sphecid Wasps (Sphecidae). The most commonly occurring beneficial insects observed on nearby crop vegetation were Green Lynx Spiders (*Peucetia viridans*), Lady Beetles (Coccinellidae), Big-eyed Bugs (*Geocoris* ssp.), Predatory Stink Bugs (Pentatomidae), and Assassin Bugs (Reduviidae). The occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation greater than 10 m distant from sunflowers in both 2002 ($F_{1,16} = 11.78$, $p = 0.003$; Figure 3-10) and 2003 ($F_{1,16} = 12.94$, $p = 0.002$; Figure 3-11). While crop vegetation 10 m distant from sunflowers harbored significantly fewer

Figure 3-9. Gut content samples obtained from birds captured after foraging in crop vegetation confirmed that economically important pest insects were consumed such as leaf-chewing caterpillars. The intestinal tracts and other internal organs of numerous caterpillars were identifiable in most stomach samples.

While crop vegetation 10 m distant from sunflowers harbored significantly fewer beneficial insects, this difference in occurrence in sunflower and crop vegetation was not seen in crop vegetation directly adjacent to sunflowers (within 1m) when this was assessed during the 2003 growing period ($F_{1,22} = 2.29$, $p = 0.144$; Figure 3-11).

Pest insects representing 12 different arthropod families were found on sunflowers and nearby crop vegetation. The most commonly occurring pest insects were Green Stink Bugs (*Acrosternum hilare*), Corn Flea Beetles (*Chaetocnema pulicaria,* Chrysomelidae) and Imported Cabbageworm larvae (*Pieris rapae* – Linnaeus) respectively. The occurrence of pest insects on sunflower and crop vegetation greater than 10 m distant from sunflowers did not significantly differ in 2002 ($F_{1,16} = 0.12$, $p = 0.74$; Figure 3-12) but did significantly differ in 2003 ($F_{1,16} = 14.7$, $p = 0.001$; Figure 3-13). Greater mean numbers of pest insects per meter were observed on sunflower vegetation than on crop vegetation greater than 10 m distant from sunflowers (2.5 individuals / m^2 vs. 0.2 individuals / m^2 respectively). This same difference was found on crop vegetation within 1 m of sunflowers as well in 2003 (2.5 individuals / m^2 vs. 0.5 individuals / m^2 respectively, $F_{1,22} = 13.4$, $p = 0.001$; Figure 3-13).

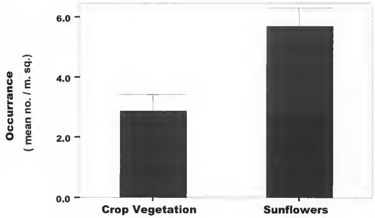


Figure 3-10. Occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation during the 2002 growing season ($F_{1,16} = 11.78$, $p = 0.003$). Error bars = 1 SE.

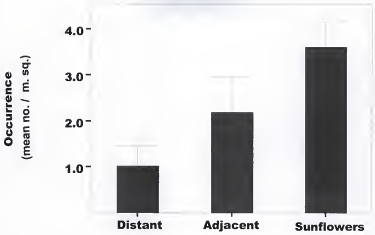


Figure 3-11. The occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation more than 10 m distant from sunflowers in 2003 ($F_{1,16} = 12.94$, $p = 0.002$). Occurrence of beneficial insects on crop vegetation directly adjacent to sunflowers (within 1m) did not significantly differ from that found on sunflower vegetation ($F_{1,22} = 2.29$, $p = 0.144$). Error bars = 1 SE.

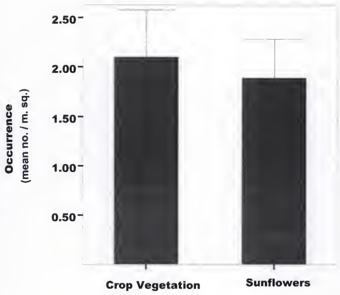


Figure 3-12. Occurrence of pest insects on sunflower and crop vegetation greater than 10 m distant from sunflowers did not significantly differ in 2002 ($F_{1,16} = 0.12$, $p = 0.74$). Error bars = 1 SE.

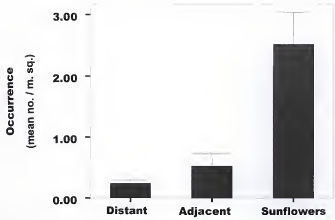


Figure 3-13. Occurrence of pest insects on sunflower and crop vegetation greater than 10 m distant from sunflowers significantly differed in 2003 ($F_{1,16} = 14.7$, $p = 0.001$). Greater mean numbers of pest insects per meter were observed on sunflower vegetation than on crop vegetation greater than 10 m distant from sunflowers (2.5 individuals / m^2 vs. 0.2 individuals / m^2 respectively). This same difference was found on crop vegetation within 1 m of sunflowers as well (2.5 individuals / m^2 vs. 0.5 individuals / m^2 respectively, $F_{1,22} = 13.4$, $p = 0.001$)

Discussion

Avian Abundance and Foraging Activity

In this study I tested the hypothesis that cropped fields with sunflower rows incorporated into the cropping system would exhibit greater bird densities. My results support this hypothesis. Those fields with even one row of sunflowers per 0.4 ha exhibited significantly greater bird densities than those without, regardless of crop type or crop diversity. While an additional increase in density was seen with an additional row of sunflowers, it appears that a single row may be enough to make cropped areas more attractive for bird use. A single row of sunflowers added to a field increased bird densities and foraging time spent by those birds nearly 4 times that seen in control blocks. Therefore the addition of a single sunflower row may provide the added structural vegetation to make a cropped field attractive for bird use in those systems where their presence could possibly provide a benefit. However, additional work needs to document and quantify the impact this increase in bird density has on insect populations in crops and crop production.

In this study I also tested the hypothesis that foraging activity would be increased in crop vegetation with the presence of sunflower rows. Results of my foraging observations support this hypothesis since foraging activity was 4 times greater in crops with sunflower rows. Previous studies suggest foraging activities of insectivorous birds in cropped systems depends upon vegetation cover and microclimate in the field (Rodenhouse and Best 1994, and reviewed by Kirk et al. 1996). Birds were found to begin to utilize sunflower vegetation as soon as the plants were able to support perching and provide some cover (Figure 3-14).

Figure 3-14. Birds were found to begin to utilize sunflower vegetation as soon as the plants were able to support them as a perch and begin to provide some cover. Once sunflowers reached a height of at least 24", birds were observed to fly in to the fields and first land on the sunflowers before venturing into nearby crop vegetation. A Palm Warbler (*Dendroica palmarum*) is shown perched on a sunflower while foraging for insects in nearby rows of kale.

Once sunflowers reached a height of at least 0.6 m, birds were observed to fly in to the fields and, first, land on the sunflowers before venturing into nearby crop vegetation. Several studies have confirmed the strong relationship between hedgerow presence and composition, and avian presence and community structure in agricultural landscapes (see O' Connor 1984, MacDonald and Johnson 1995). Therefore in those fields in which birds may provide a benefit as insect predators, the addition of sunflowers into the cropping system may be an effective and temporary habitat modification.

I observed birds actively pursuing and consuming economically important pest insects gleaned from crop vegetation. The value of utilizing naturally occurring enemies cannot be overemphasized within organic farming systems and IPM programs (Rosen et al. 1996). Insectivorous birds are naturally occurring components of agroecosystems and their feeding activities in and around cropped areas may be of great economic value. Birds are both mobile enough to recruit readily to high-density food patches in their home ranges, and are capable of complex prey-switching and specialization behaviors (McFarlane 1976, Kirk et al. 1996). Due to these characteristics birds are potentially important components of biological control regimes, provided they increase the natural mortality of agricultural arthropod pests without adversely affecting other natural enemies and the crops themselves (McFarlane 1976, Kirk et al. 1996).

As pest predators, birds may provide both numerical and functional responses to prey availability over short time periods and large areas (Holling 1988, Dahlston et al. 1990, Holmes 1990) – potentially stabilizing pest communities in agroecosystems,

augmenting the activities of other classes of predators with different characteristics (Price 1987, Rosen et al. 1996, Helenius 1998). Since birds responded to the presence of sunflower rows after they reached a certain height, timing of planting of these rows will be critical to maximize the benefit of attracted insect predators to crops. Sunflower plantings should proceed that of other crop vegetation by several weeks to allow their establishment and potential attraction of beneficial predators before crops, and any associated pests, reach critical growth stages. Optimally, potential suppression of pest insects will occur if an adequate predator base is present before pests colonize crop vegetation and their populations grow to economically damaging levels (Price 1987, Rosen et al. 1996, Helenius 1998).

Most bird damage to crops in the U.S. occurs to grain and small sized fruit crops appear to be worse in certain regional locations, certain cropping system designs, and in crops bred for very early or late season harvests (reviewed by Rodenhouse et al. 1995). Several bird species are known to cause considerable damage to crops, especially flocking species such as Red-winged Blackbirds (*Agelaius phoeniceus*) and Cedar Waxwings (*Bombycilla cedrorum*). During my 4 years of observations of birds in cropping systems I observed very little damage to vegetable crops by birds. During the spring growing season of 2001, North-central Florida experienced severe drought conditions. In this season I observed watermelon damage cause by American Crows (*Corvus brachyrhyncos*) presumably to obtain water. In all 4 years, 2000 – 2003, I also observed a limited amount of strawberry damage caused by Northern Mockingbirds (*Mimus polyglottos*). During this study participating farmers reported that they did not experience any increase in bird

damage due to attracting more birds into their cropping systems with sunflower plantings. I did not observe any of the 3 most problematic species mentioned above utilizing sunflowers (blackbirds, crows, or waxwings) or being attracted to plots with sunflower rows over the study period.

In a recent survey of Florida farmers, bird damage to crops was reported by 32.9% of the survey participants primarily indicating damage to watermelon or corn by crows (Jacobsen et al. 2003). However only 11.8% reported the need to utilize bird control methods to limit damage. In some cases proper "farmscaping" cannot only increase the presence of beneficial organisms, but may reduce the presence or abundance of problematic species in cropping systems as well. Farmscaping is defined as a whole-farm, ecological approach to pest management through selective placement of hedgerows, insectiary plants, cover crops, and water reservoirs to attract and support populations of beneficial organisms such as insects, bats, and birds of prey (http://attra.ncat.org/attra-pub/PDF/farmscaping.pdf). Research in farmscaping to maximize beneficial organisms and limit pests is ongoing to identify and develop such management strategies (Pickett and Bugg 1988, Bommarco and Ekbom 2000).

Beneficial and Pest Insect Occurrence

Insect sampling efforts revealed that sunflowers did indeed attract and play host to numerous beneficial insects as has been described in numerous publications (Henn et al. 1997, UF Coop. Ext. Service Insect Identification Sheets SPSET 5 1997). Sunflower plants were found to attract predaceous insects almost immediately after establishment. Parasitoids and pollinators were attracted as soon as these plants began to produce flowers. These same beneficial insects were found to also occur on

crop vegetation but in lower numbers. It has been found in several studies that providing predator refugia within cropping systems via strip crops or uncultivated corridors can result in the migration of predatory insects into adjacent crops (see Johanowicz and Mitchell 2000, Mensah 1999, Nentwig 1998, Schoenig et al. 1998, Wratten et al. 1998, Rodenhouse et al. 1992). In the 2003 growing season I modified the sampling methodology in an attempt to determine whether beneficial insects attracted to the sunflowers may have been moving out from the sunflowers into adjacent crop vegetation. Results indicated that crop vegetation 10 m distant from sunflowers harbored significantly fewer beneficial insects than did that within 1 m. Moreover, crop vegetation within 1 m of sunflowers exhibited nearly the same abundance and diversity of beneficial insects as did the sunflowers themselves. Further study is required to fully describe the distances key beneficial insects move from sunflowers and the impact these beneficial insects have on crop pests.

Conclusion

Bird populations and avian community structure are known to respond differently to the distribution of cropped and non-cropped landscape elements and the distribution, relative cover classes, and juxtaposition of agricultural landscape elements in agroecosystems (Freemark et al. 1993, Rodenhouse et al. 1993). Intrinsic habitat qualities such as food resources or shelter availability play important roles in habitat selection by birds (Bairlein 1983, Martin and Karr 1986, Moore et al. 1995). Moreover, habitat complexity resulting from a mix of different plant species, percentages of vegetative cover and variations in the size, distribution, and

juxtaposition of plant assemblages will influence the local diversity of bird species (James 1971). The addition of structurally diverse vegetation strips within cropped fields appears to attract and provide cover for birds utilizing adjacent non-crop habitats. In so doing the probability that these highly insectivorous animals may provide an economic benefit to producers is greatly increased. In return, the creation of suitable habitat within cropping systems may aid in the conservation of all avian species within agroecosystems. Within the discipline of conservation biology there is increasing recognition that protected reserves alone will not be sufficient to conserve biodiversity in the long term; therefore, methods of integrating conservation and productive use must be achieved (Hobbs and Norton 1996). This study contributes to a better understanding of the effects of vegetative structure and crop species composition on farm-bird community structure, with more general applications to implementation of environmentally sensitive agriculture.

CHAPTER 4
PARASITIZED AND NON-PARASITIZED PREY SELECTIVITY OF INSECTIVOROUS BIRDS: POTENTIAL FOR AUGMENTATION OF CLASSICAL BIOCONTROL

Introduction

Biological control by natural enemies is the most successful and promising alternative to unilateral reliance on chemical pesticides in low input cropping systems (Rosen et al. 1996). Classical biological control programs often rely on releasing introduced (non-native) parasitoids to reduce exotic pest populations (DeBach and Rosen1991), where host specificity is emphasized using parasitoids or predators of targeted pest arthropods. While a majority of biological control research has focused upon "specialist" enemies for individual agricultural pests, the strategy of enhancing these efforts by increasing "background mortality" (see Beddington et al. 1978) through assemblages of native generalist predators also shows promise in crop management schemes (Helenius 1998). Such augmentation of classical biological control programs will require sustained availability of large numbers of inexpensive, high quality, naturally occurring predators (Hoy 1992). Multiple natural enemies in a system are understood to provide a shifting temporal and spatial mosaic of predation rates across multiple prey, dampening variability in the systemic predator-prey dynamic (Rabb 1971). Thus augmentation of classical biological control measures involves efforts to enhance the presence of naturally occurring enemies of pest arthropods in agroecosystems.

Over the past 2 decades, field entomologists and agronomists have increasingly recognized that the conservation of natural enemies via the management of non-cropped habitats that support them is important to effective and successful biological control in agricultural systems (Rosen et al. 1996). However, little work has been done looking at avian insect predators in modern cropping systems to fill this role of augmenting other control measures. One particularly important potential mechanism whereby birds might stabilize and augment pest control is consumption of individual prey that escape mortality from other agents of biological control. In systems where introduced or native parasitoids are supported via provision of critical habitat (e.g., insectiary plantings) rather than through repeated releases onto fields, parasitism rates undergo fluctuations due to parasitoid population lags (Bugg and Pickett 1998). In such systems birds could function to stabilize and maintain sufficient pest mortality rates given their abilities to respond functionally to changes in prey abundance (McFarlane 1976). While this scenario reasonably explains how birds could effectively augment arthropod pest mortality induced by parasitoids typically employed in classical biological control regimes (McFarlane 1976, Kirk et al. 1996), its generality, practicality, and economic efficiency have not been assessed for any agroecosystem.

Bruns (1959) stated that birds would be of value as insect predators in a system only if they increase the effectiveness of control by taking insects over and above those that would normally have been destroyed by other agents. Several studies have demonstrated that birds select and consume non-parasitized insects suggesting that bird predation may be additive to the mortality caused by parasitoids (Sloan and Simmons 1973, Schlichter 1978). Sloan and Simmons (1973) reported that hymenopterous

parasitized jack pine budworm (*Choristoneura pinus* Bechstein) larvae and pupae were unanimously rejected by foraging chipping sparrows (*Spizella passerina*). Similarly, Schlicter (1978) reported that black-capped chickadees (*Parus atricapillus*) largely avoided foraging upon galls on Canada goldenrod (*Solidago canadensis*) that had been parasitized by mordellid beetle (*Mordellistena unicolor*) larvae to extract gall fly (*Eurosta solidaginis*) larvae. Therefore it appears that birds have the ability to distinguish prey that have been damaged or may be compromised by a parasite and avoid such prey.

Previous observations have confirmed that many birds occurring in cropped fields of North-central Florida actively forage for and consume caterpillars in crop vegetation (see Chapters 2 and 3). Fall armyworms [Lepidoptera: Noctuidae, *Spodoptera frugiperda* (J. E. Smith)] are important pests in vegetable and row crops (Johnson and Sprenkel 1996) and are often subjected to biological control using cultured parasitoids (R. Meagher, USDA-ARS, Center for Medical, Agricultural and Veterinary Entomology (CMAVE), Gainesville, FL, pers. comm., Johnson and Sprenkel 1996). Parasitoids are insects whose eggs are deposited on another arthropod (usually an insect) host, its larvae, or in the host's egg. The resultant larvae develop by feeding upon the bodies of the host resulting in the host's death (Godfray 1994).

In this study I addressed whether birds would consume armyworms that had been parasitized or avoid such prey. I tested the hypothesis that birds prefer to forage upon non-parasitized armyworm prey via captive feeding trials where birds were also offered prey parasitized by Euplectrus wasp larvae. In both studies where birds avoided prey, it was suggested that visual cues were utilized to distinguish between prey types (Sloan and

Simmons 1973, Schlichter 1978). Parasitoids can be divided into two classes by the feeding behavior of their larvae. Endoparasitoid larvae feed from, and develop within, the body of their host. Ectoparasitoid larvae develop while externally attached to the host feeding with mouthparts buried into the host's body (Godfray 1994). Larvae of the genus *Euplectrus* are gregarious (more than one parasitoid larvae per host) external parasites of lepidopteran larvae. *Euplectrus* larvae remain attached to the exoskeleton and feed on the dorsum of their host, which is often still able to move freely about (Figure 4-1). Once the *Euplectrus* larvae mature they move below the emaciated host to pupate, spinning silk from the host's Malpighian tubes which hold the host down and separate the larvae from each other (Grissell and Schauff 1997). Therefore, *Euplectrus* served as a good representative of commonly occurring ectoparasitoids whose larvae develop on the external surface of their host that could be visually identified by a bird.

Methods

Research Facilities and Test Species

Feeding trials were conducted in an aviary at the USDA National Wildlife Research Center's Florida Field Station, Gainesville, Florida. Red-winged blackbirds (*Agelaius phoeniceus*) captured in agricultural settings and housed at the field station were utilized as a test insectivorous species. This species was chosen due to the fact that individuals of this species commonly occur in agricultural landscapes (Ehrlich et al. 1988, Dolbeer 1990) and have been previously examined for their predatory impact on insect pest populations in crops (Bendell et al. 1981). Birds were presented parasitized and non-parasitized fall armyworms provided by the USDA- ARS CMAVE, Gainesville,

FL. Parasitized armyworm larvae were those that had been exposed to and carried larvae of the Eulophid parasitoid species *Euplectrus plathypenae* (Howard). This Hymenopteran species commonly occurs in Florida and has been investigated for its biological control value (R. Meagher, USDA-ARS, Center for Medical, Agricultural and Veterinary Entomology (CMAVE), Gainesville, FL, pers. comm.).

Paired Feeding Trials With Non-parasitized Larvae

The first set of feeding trials performed with non-parasitized prey test if the captive birds would feed upon fall armyworms, and I determined their baseline consumption given this food item. Only those birds willing to readily eat armyworms were utilized for subsequent tests. Additionally, since birds have exhibited prey size selectivity when presented a choice (Krebs et al.1977, Davies 1977, Zach 1979) an assessment was made whether birds exhibited a feeding preference for different instar sizes of these caterpillars. Maintenance food was removed by 0700 EST and 1-2 hrs later birds were presented with a plastic cup divided into two chambers (Figure 4-2). In the first pretests, 10 armyworms of equal size were simultaneously presented in the cup's chambers and birds were allowed to forage undisturbed for ½ hour (Figure 4-3). The propensity of each bird to eat the armyworms, the chamber location (left or right side of cup) the larvae were chosen from, and the time it took for the bird to consume all 10 larvae were noted. In these tests, as well as all that followed in this study, a bird would not be given a subsequent test presentation until at least 1 hour had passed.

In the second set of tests, those birds that had exhibited a willingness to eat armyworms in the first tests were simultaneously presented 10 larvae of two different instar sizes, 5 large (5^{th} instar, 26.1 ± 3.0 SD mm, $n = 28$) vs. 5 small (2^{nd} or 3^{rd} instar,

Figure 4-1. *Euplectrus plathypenae* Howard (Hymenoptera: Eulophidae) larvae attached to an armyworm (*Spodoptera ssp.*) larvae host.

Figure 4-2. Prey item presentation cup placed in test cage with a red-winged blackbird (*Agelaius Phoeniceus*) foraging for a food item. The presentation cup contained a center divider partitioning the cup into two chambers. A red line painted on the exterior of the cup allowed observers to easily determine which chamber a food item was taken from.

Figure 4-3. In multiple trials, birds were offered fall armyworms [*Spodoptera frugiperda* (J. E. Smith)] of similar body size in each of the presentation cup's chambers.

14.5 ± 2.4 SD mm, n = 28), presented in a plastic cup divided into two separate chambers (Figure 4-4). Birds were allowed to forage until 5 armyworms were consumed or ½ hour had elapsed, which ever occurred first. Choice of prey size and order of prey taken was recorded each time a bird chose to consume a larva and choices ranked first to last taken.

Prey Recognition Trials

In prey recognition trials, birds were simultaneously offered a paired choice of parasitized and non-parasitized fall armyworms (following methods described by Avery et al. 1994 & 1999). Maintenance food was removed by 0700 EST and 1-2 hrs later birds were presented with a plastic cup divided into two chambers, one containing 5 parasitized armyworms the other containing 5 non-parasitized armyworms. Birds were allowed to forage undisturbed for 15 minutes or until 5 caterpillars were selected. Position of prey type in the cup's 2 chambers (left side or right side) was alternated for each trial. In each trial the order and number of each prey item taken was noted and choices ranked first to last taken. The objective of these paired trials was to document immediate prey preference response and overall preference of individual birds to parasitized and non-parasitized prey choices.

In the first set of these prey recognition-feeding trials, birds were presented parasitized and non-parasitized armyworms of equal body size. Therefore birds were presented a choice of prey differing only in the appearance of having attached parasitoid larvae or not. The second set of prey recognition trials presented parasitized and non-parasitized armyworms of equal age. Host larvae that have had a *Euplectrus* female oviposit or attempt to oviposit an egg in them exhibit arrested growth thereafter. This is a typical host response to venom of *Euplectrus* injected during oviposition (Coudron and

typical host response to venom of *Euplectrus* injected during oviposition (Coudron and Puttler 1988). The resultant arrested growth causes a substantial size difference to develop between parasitized and non-parasitized armyworms within 24 - 48 hours (Figure 4-4).

Data Analysis

Initial preference for choosing the first prey item from 1 of the 2 cup chambers (right vs. left), size (large vs. small), or parasitized vs. non-parasitized prey was determined in the paired trials using Chi-square tests of the null hypothesis that birds chose from each side of the cup or prey type with equal frequency. Overall prey preference was determined utilizing stratified Wilcoxon rank sum tests of the null hypothesis that birds show no preference for feeding upon the paired prey types. Of the five bird selections, the first food selected by the bird receives rank 5, the second rank four, etc. and the fifth receives rank 1. All ranks assigned to a particular food are then summed over the many birds in the trial. A preferred food would receive higher ranks and more ranks than a food that was less preferred. The null hypothesis for the rank sum is derived by assuming that each bird randomly selects its next food item, so that selections are made as though an honest coin (having probability of 1/2 of selecting each of the two foods) is tossed each time a food item is selected by the bird. Thus each rank is randomly assigned to one of the foods based on an independent coin toss. Violations of this assumption causing one of the foods to receive higher rank totals can then be assessed via a p-value computed under this null distribution. A small p-value thus indicates a strong preference for one of the two foods (R. H. Randles and M. Capanu, IFAS Statistics, University of Florida, FL, Pers. Comm.)

Figure 4-4. In multiple trials, birds were offered fall armyworms [*Spodoptera frugiperda* (J. E. Smith)] of significantly different body size in each of the presentation cup's chambers.

Results

Tests with non-parasitized larvae found that most birds (14 out of 18 individuals) would quickly consume the 10 larvae presented to them. In 80% of the trails, birds consumed all 10 larvae presented to them within 15 minutes, regardless of instar size. Typically, each bird would mandibulate the larvae up and down its entire length before swallowing (especially so for the largest larvae). This handling often caused the larvae to exude a gut secretion, which was allowed to fall to the cage floor. Sloan and Simmons (1973) observed similar behavior and suggested that lepidopteran gut secretions may be distasteful to birds, leading to this behavior.

Birds showed no initial preference for feeding from a particular chamber (right or left side) of the presentation cup ($\chi^2 = 0.05$, $p > 0.05$, $n = 19$). Birds did exhibit a significant initial preference for larger armyworms when presented a size difference in prey ($\chi^2 = 28.30$, $p > 0.001$, $n = 20$). Birds also showed a significant overall preference for larger prey even while this prey item became increasingly less numerous in the cup during each trial ($Z = -3.63$, $p < 0.001$, $n = 20$).

In prey-recognition trials, birds were readily willing to eat both parasitized and non-parasitized prey offered to them. Interestingly, some of the *Euplectrus* larvae became detached from their host when birds handled the caterpillars and often remained behind in the presentation cup. When the cup was left in the cage, birds often consumed the free *Euplectrus* larvae. Birds did not exhibit an initial preference between simultaneously presented parasitized and non-parasitized armyworms of the same size ($\chi^2 = 1.0$, $p > 0.05$, $n = 20$). Likewise, birds did not exhibit an overall preference between these prey types in the cup during each trial ($W_O = 139$, $p = 0.69$, $n = 20$). However as

expected, birds did exhibit a significant initial preference for larger non-parasitized armyworms versus the smaller parasitized prey of the same age ($\chi^2 = 38.44$, $p > 0.001$, $n = 21$). Birds also showed a significant overall preference for the larger non-parasitized prey ($W_O = 248$, $p < 0.001$, $n = 21$) even while this prey item became increasingly less numerous in the cup during each trial (Figure 4-5).

Discussion

Birds will augment pest control programs if they consume individual prey that have escaped mortality from other agents of biological control in the cropping system. In this study, the hypothesis that birds prefer to forage upon non-parasitized prey was tested and found to be functionally valid although via a different mechanism than I expected. Red-winged blackbirds were equally willing to eat both parasitized and non-parasitized fall armyworm prey of the same body size. However, in the case examined in this study, birds showed a strong preference for the larger lepidopteran prey confirming findings by Krebs et al. (1977). Fall armyworm larvae that have escaped parasitism quickly become larger in body size compared to those parasitized by *Euplectrus* wasps. Birds overwhelmingly preferred these larger caterpillars when they were given a choice between the 2 prey types and subsequently avoided parasitized prey. This supports previous work indicating that birds avoid prey that have been damaged or compromised by a parasite.

Sloan and Simmons (1973) observed that the avoidance of parasitized prey items by chipping sparrows appeared to be related to a size difference between parasitized and non-parasitized jack pine budworms. Similar to larvae stung by ovipositing *Euplectrus*

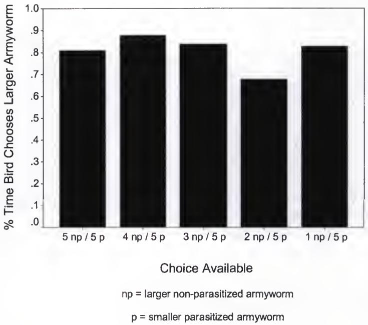


Figure 4-5. Birds showed a significant overall preference for the larger non-parasitized prey ($W_o = 248$, $p < 0.001$, $n = 21$) even while this prey item became increasingly less numerous in the cup during each trial. Birds overwhelmingly chose a larger larvae in each case of choice pairings from 5 larger non-parasitized with 5 smaller parasitized to pairings of only 1 non-parasitized with 5 smaller parasitized fall armyworms [*Spodoptera frugiperda* (J. E. Smith)].

wasps, those jack pine budworms that had been parasitized by *Apantales fumiferanae* Viereck (Hymenoptera: Braconidae) are comparatively small. Since many parasitoid wasps, such as those in the genus *Euplectrus*, cause a significant difference in body size to develop between hosts and those lepidopteran larvae missed by these parasitoids, birds preferentially foraging for larger caterpillars could indeed increase overall mortality of these pests in cropping systems. Difference in size occurs between those caterpillars that are parasitized and those that have not been attacked by *Euplectrus* and similar wasps, regardless if the caterpillar actually carries wasp larvae or not. Continued molting for growth to larger instars is arrested in caterpillars that have been stung by these wasps in attempts to oviposit even if eggs where not actually deposited or develop successfully (Coudron and Puttler 1988, Coudron et al. 1990).

Foraging upon leaf-eating caterpillars that have escaped control by parasitoid wasps, such as *Euplectrus* ssp., could indeed be of great value to a producer. Parkman and Shepard (1981) measured the difference in foliage consumption between parasitized (by *E. plathypenae*) and non-parasitized yellowstriped armyworms (*Spodoptera ornithogalli*) and found parasitized larvae consumed significantly less foliage (1.23 vs. 8.85 cm^2 / d / larvae). Additionally, Coudron et al. (1990) found that in most cases parasitized caterpillars cease to feed altogether due to this arrested growth condition. Therefore, it is very important in an integrated pest management system to include an additional predator that exhibits a preference for feeding on those lepidopteran larvae that have escaped attack by parasitoids of this kind.

In this study most red-winged blackbirds were more than willing to eat fall armyworms and were capable of consuming a number of these prey in short time periods.

In cropped fields where armyworms are problematic, insectivorous birds may provide a benefit by consuming this prey item. For example, Bendell et al. (1981) found that predation by red-winged blackbirds was responsible for lowering overwintering European corn borer [*Ostrinia nubilalis* (Hübner), Lepidoptera: Pyralidae] populations in standing corn of the following year. Unfortunately, red-winged blackbirds can also cause damage to many fall ripening row crops. This damage can be especially high in fields nearest to their favored roost habitats (wetlands), where large flocks congregate (Dolbeer 1990).

Results of this study suggest that birds may indeed augment biological control programs when those arthropod pests that escape control become distinctly different in body size and subsequently a favored prey item. However, feeding bebavior of birds in the field may be substantially different than that in a laboratory setting. Krebs et al. (1977) found that when prey items were scarce, birds chose to eat large and small food items equally. Birds began to exhibit a preference for large prey when large and small food items were in abundance. Additionally, the behavior of parasitized verses non-parasitized prey may affect the vulnerability of parasitized lepidopteran larvae to avian predation in a field setting. The fitness of an organism that parasitizes another is not only a function of its own survival and reproduction but also upon the survival of its host (May and Anderson 1983). There is growing evidence that parasitoids may manipulate the behavior of their hosts to their advantage (reviewed by Godfray 1994). More? Therefore, these aspects of the interaction of avian predators and arthropod pest prey subject to biocontrol need further investigation within cropping systems.

Conclusion

In the U.S., resident and migratory passerines (over 200 different species) constitute more than 70% of the bird species that feed, roost, or breed on agricultural lands (Rodenhouse et al. 1993). Fortunately, few landbird species indigenous to the U.S. are pests to crops, and less than 10 are known to cause significant damage to any crop (Dolbeer 1990). Many species occurring in the U.S. are wholly or partly insectivorous (Freemark et al. 1991) and as such have great potential for stabilizing insect populations including crop pests thus enhancing plant growth via insectivory.

Biotic diversity is a vital and irreplaceable component of our natural resources providing ecosystem services that are essential to agriculture (Ehrlich et al. 1995, Daily 1997a). In a recent survey of farmers in Florida, 80% of conventional farmers (non-organic) indicated that they considered leaf-eating insects a serious pest problem (Jacobsen et al. 2003). In another survey, leaf-eating caterpillars were the most frequently mentioned type of insect pest by Florida organic farmers; armyworms were specifically mentioned (Swisher et al. 1994). Observations of birds foraging in cropping systems have confirmed that birds actively seek out and consume crop pest lepidopteran larvae (see Chapter 3). While numerous researchers in the past purported the value of bird predation, few modern studies have quantified their potential as agents of biocontrol in cropping systems (see Kirk et al. 1996, McFarlane 1976). This study aids in the determination of the pest control potential avian insect predators have in agroecosystems and increases our understanding of the functional role of insectivorous birds in modern agricultural systems. Information obtained from captive feeding trials can be incorporated into estimates of overall pest regulation potential and sets the stage for

future field research to investigate actual arthropod biomass reductions due to foraging by insectivorous birds in cropping systems (i.e. exclosure studies etc.).

CHAPTER 5
SUMMARY AND FUTURE RESEARCH NEEDS

Summary

I examined factors influencing avian species diversity on North-central Florida farmlands and, in particular, focused upon factors that increased the presence and abundance of insectivorous birds and their foraging activity in cropped fields. I assessed overall avian biodiversity on a selection of conventional and certified organic farms, and identified farm characteristics correlated with bird diversity. I also identified 'functional insectivores' among the bird species utilizing farmlands and identified farm characteristics correlated with densities of these species in cropped fields. I found that many birds, including several listed as species of conservation concern by both the Federal Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission, utilize croplands. Encouragingly, a large percentage of species that might be expected to occur in North-central Florida croplands, based upon the Audubon of Alachua County checklist of birds and BBS census data from the county, were observed utilizing these landscapes. This would suggest that the agricultural landscape composed of the small- to medium-size farmsteads typical of this region offer suitable habitats for a large number of species.

Avian species abundances and diversity on farms was strongly influenced by the presence of complex hedgerows and windbreaks of natural vegetation bordering cropped fields. Likewise, abundances of functional insectivores were also strongly influenced by the presence of these farmscape elements. Moreover, the landscape matrix adjacent to cropped fields, which serves as source areas of birds to the farm, in combination with complex hedgerows and windbreaks was found to be very important in determining bird densities in cropped fields. These results emphasize that the dominant vegetative communities in landscapes where farms and farm fields are embedded, as well as the composition and spatial configuration of habitat, determine bird species diversity on farms. These results also suggest that schemes to design on-farm habitats (crops, field borders, and location of planted fields with respect to adjacent matrix types) to influence bird diversity could be effective, very flexible, accommodate different classes of birds (i.e. woodland, grassland, edge, generalist species), and therefore, could be excellent tools for avian conservation in agroecosystems.

In apparent contradiction with other studies in North America (Freemark and Kirk 2001, Beecher et al. 2002) and Europe (Christensen et al. 1996, Chamberlain et al. 1999) that documented significantly greater bird diversity associated with organic farming practices, I detected only slight enrichment of bird diversity in organic versus conventional farming systems of North-central Florida. This could be a factor of the smaller size of the farms surveyed in the study and the heterogeneity of the North-central Florida landscape compared to other studies. Crop diversity proved to be a very strong predictor of bird density

on the farms. Since many conventional farms surveyed in this study employ polyculture management, this factor appeared to out weigh the differences in bird occurrence that may have been generated by chemical applications to crops. Therefore avian conservation efforts in farmlands should emphasize the value of polyculture cropping systems.

I found a large number of insectivorous bird species utilizing cropped fields of North-central Florida to forage in. Direct observations during foraging bouts indicated that most of these species were actively capturing insect prey from crop vegetation. One important determination I made during this study is that without determining what birds eat when they are in fields, farmers may assume that all species are detrimental to crops since a few species can be significant pests in agroecosystems. Because many birds species are insectivores, or are insectivorous to some degree, and most become highly insectivorous during the breeding season to support their energetic needs and those of their nestlings, I advocate the utility of these 'functional insectivores' on farms. This work supports the general assessment that the ecological role of birds, as insect predators in agroecosystems, is likely to realize enhanced production and economic value to farmers. Therefore, through an increased awareness of the functional role that insectivorous species may have in cropping systems, producers should be encouraged to engage in avian conservation efforts on their lands.

I found that the occurrence, density, and especially foraging activity of insectivorous birds in polyculture cropping systems I surveyed were highest in

those having sunflowers (*Helianthus annuus*) and other decorative cut flowers intercropped between vegetable rows. I tested the hypothesis that cropped fields with sunflower rows incorporated into the cropping system would exhibit greater bird densities and found in those fields with even one row of sunflowers intercropped within it exhibited significantly greater bird densities than those with no sunflowers. The addition of even a single sunflower row per acre may provide the added structural vegetation to make a cropped field attractive for bird use in those systems where their presence can provide a benefit. Foraging activity by functional insectivores also was greatly enhanced by this sunflower treatment. Additionally, intercropped sunflowers attracted and played host to numerous beneficial insects, and these insects attracted to the sunflowers appeared to move from them into nearby crop vegetation. Therefore, in those fields in which birds (and predatory insects) may provide a benefit as insect predators, the addition of sunflowers into cropping systems may be an effective, and temporary habitat modification.

Birds can be of value as insect predators in a cropping system only if they increase the effectiveness of control by taking insects over and above those that would normally have been destroyed by other agents (Bruns 1959). My foraging observations of birds in cropping systems have confirmed that birds actively seek out and consume crop pests. Birds will augment pest control programs such as those that utilize parasitoids of the crop pests if they consume individual prey that have escaped mortality from such agents of biological control. I observed that birds exhibit a strong preference for larger prey when given a choice, even when

that prey item is not the most numerous available. Since many parasitoid wasps often utilized in biological control cause a significant difference in body size to develop between hosts and those prey missed by these parasitoids, birds preferentially foraging for larger prey could indeed increase overall mortality of many pests in cropping systems.

Future Research Needs

Biotic diversity is a vital and irreplaceable component of our natural resources providing ecosystem services that are essential to agriculture (Ehrlich et al. 1995, Daily 1997). While numerous researchers in the past purported the value of bird predation, few modern studies have quantified their potential as agents of biocontrol in cropping systems (see Kirk et al. 1996, McFarlane 1976). My work aids in the determination of the pest control potential avian insect predators have in agroecosystems and increases our understanding of the functional role of insectivorous birds in modern agricultural systems. However, many questions remain that need to be addressed before biological control enhancement can be developed manipulating populations of avian species identified as potentially beneficial currently existing in, or that could be attracted to these systems. Further, investigations of avian insectivory as a component of pest management schemes that are consistent with ecologically sound agriculture are needed, and the actual impact avian insectivory has in these systems needs to be quantified.

While landscape matrix and farm-scale habitat characteristics that appear to support avian populations are identified, annual breeding productivity and survival of birds nesting in North-central Florida agroecosystems needs to be assessed. If avian conservation and agricultural production are to be truly integrated, these systems must not only attract birds but also be capable of sustaining species populations that have been attracted. Management that creates farmland structure that attracts birds, when combined with harmful agricultural practices (those that cause adult or nestling mortality), or with an over abundance of avian predators, can become ecological traps functioning as population sinks for avian species (reviewed by Rodenhouse et al. 1995). Therefore, farmland management to provide suitable habitat for birds must be such that optimize survivability and nesting success for those species attracted to such systems. Evaluation of farmscapes in regard to breeding success must be performed in differing agroecosystems to aid in the development of systems that will sustain the greatest avian diversity and abundance.

Conclusion

Ornithologists have suggested that changes in agricultural practices and landscape structure over the past few decades have reduced the favorability of farmland habitat elements many farmland species had traditionally utilized. The current landscape of North-central Florida appears to represent a 'patch mosaic' of diverse habitat types long recognized as essential for the maintenance of bird (and other) species on farmlands (birds; O'Conner and Boone 1992, Best et al.

1995: plants; Freemark et al. 2002: moths; Ricketts et al. 2001: ants; Perfecto and Vandermeer 2002). Farms of all sizes in Florida agroecosystems represent a diversity of soil types, climatic conditions, cropping systems, landscapes, biological organization, culture, and traditions. This diversity mirrors and compliments that of Florida's many different natural ecosystems. The potential for responsible management of soil, water, and wildlife encompassed by Florida's farms produces an opportunity for significant environmental sensitivity by our agricultural producers. As imperatives for agricultural shift from the single goal of increasing unit-area production to environmentally sustainable systems, an excellent opportunity exists to match the aspirations of Florida's farmers with needs of native birds.

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APPENDIX A

BIRD SPECIES OBSERVED DURING CENSUS SURVEYS IN NORTH-CENTRAL FLORIDA FARMLANDS

Table A-1. Species observed during census surveys in cropped fields (F) or within 50 m of cropped fields (M) of organic (O) and conventionally (C) managed farmlands (or both; B) of North-central Florida during breeding seasons 1 May through 30 June 2000 and 25 April through 30 June 2001. Species observed foraging within crop vegetation are indicated with an asterisk and the 10 most common of those (i.e., functional insectivores) are in bold face type. Conservation status of species is indicated in the right column, according to the US Fish and Wildlife Service (FWS) and Florida Fish and Wildlife Conservation Commission (FWC; CC = conservation concern (after Millsap 1990, revised), T = threatened, SSC = species of special concern).

Common Name	Scientific Name	Farm	Habitat	Status
Acadian Flycatcher	*Empidonax virescens*	O	M	CC - FWC
American Bald Eagle	*Haliaeetus leucocephalus*	C	M	T – FWS
American Crow *	*Corvus brachyrhynchos*	B	FM	
American Kestrel	*Falco sparverius*	O	F	SSC – FWS
American Redstart *	*Setophaga ruticilla*	O	FM	CC - FWC
Barn Swallow	*Hirundo rustica*	C	FM	
Bay-breasted Warbler *	*Dendroica castanea*	O	FM	CC - FWC
Black Vulture	*Coragyps atratus*	C	FM	
Black-and-white Warbler *	*Mniotilta varia*	C	FM	CC - FWC
Blackpoll Warbler *	*Dendroica striata*	B	FM	CC - FWC
Blue Grosbeak *	***Guiraca caerulea***	**B**	**FM**	
Blue Jay *	*Cyanocitta cristata*	B	FM	
Blue-gray Gnatcatcher *	*Polioptila caerulea*	B	FM	
Blue-headed Vireo	*Vireo solitarius*	O	M	
Boat-tailed Grackle *	*Quiscalus major*	O	F	
Bobolink *	*Dolichonyx oryzivorus*	O	FM	CC - FWC
Brown Thrasher *	***Toxostoma rufum***	**B**	**FM**	

Table A-1. Continued.

Common Name	Scientific Name	Farm	Habitat	Status
Brown-headed Cowbird *	*Molothrus ater*	B	FM	
Carolina Chickadee *	*Parus carolinensis*	B	FM	
Carolina Wren *	*Thryothorus ludovicianus*	B	FM	
Cattle Egret *	*Bubulcus ibis*	B	F	
Cedar Waxwing	*Bombycilla cedrorum*	B	M	
Chimney Swift	*Chaetura pelagica*	B	FM	
Common Grackle	*Quiscalus quiscula*	B	F	
Common Ground Dove *	*Columbina passerina*	B	FM	SSC – FWS
Common Yellowthroat *	*Geothlypis trichas*	B	FM	
Downy Woodpecker *	*Picoides pubescens*	B	FM	
Eastern Bluebird *	***Sialia sialis***	**B**	**FM**	**CC - FWC**
Eastern Kingbird *	*Tyrannus tyrannus*	B	F	CC - FWC
Eastern Meadowlark *	*Sturnella magna*	B	FM	CC - FWC
Eastern Towhee	*Pipilo erythrophthalmus*	B	M	
Eastern Tufted Titmouse	*Parus bicolor*	B	M	
Eastern Wood-pewee	*Contopus virens*	O	M	
European Starling	*Sturnus vulgaris*	B	FM	
Fish Crow	*Corvus ossifragus*	B	FM	
Gray Catbird *	*Dumetella carolinensis*	B	FM	
Great Crested Flycatcher *	***Myiarchus crinitus***	**B**	**FM**	
Great Horned Owl	*Bubo virginianus*	O	M	

Table A-1. Continued.

Common Name	Scientific Name	Farm	Habitat	Status
Green Heron	*Butorides striatus*	O	F	
House Finch *	*Carpodacus mexicanus*	B	F	
Indigo Bunting *	***Passerina cyanea***	**B**	**FM**	**CC - FWC**
Killdeer	Charadrius vociferus	C	FM	
Loggerhead Shrike *	***Lanius ludovicianus***	**B**	**FM**	**SSC – FWS**
Mississippi Kite	*Ictinia mississippiensis*	B	M	CC - FWC
Mourning Dove *	*Zenaida macroura*	B	FM	
Northern Bobwhite *	*Colinus virginianus*	B	FM	CC - FWC
Northern Cardinal *	***Cardinalis cardinalis***	**B**	**FM**	
Northern Mockingbird *	***Mimus polyglottos***	**B**	**FM**	
Northern Parula *	*Parula americana*	B	FM	
Orchard Oriole *	***Icterus spurius***	**B**	**FM**	
Ovenbird	*Seiurus aurocapillus*	O	M	CC - FWC
Pileated Woodpecker	*Dryocopus pileatus*	B	M	
Pine Warbler	*Dendroica pinus*	B	M	CC - FWC
Purple Martin	*Progne subis*	B	FM	CC - FWC
Red-bellied Woodpecker *	*Melanerpes carolinus*	B	FM	
Red-eyed Vireo	*Vireo olivaceus*	B	M	CC - FWC
Red-headed Woodpecker *	*Melanerpes erythrocephalus*	O	F	SSC – FWS
Red-shouldered Hawk *	*Buteo lineatus*	B	FM	
Red-winged Blackbird *	*Agelaius phoeniceus*	B	FM	

Table A-1. Continued.

Common Name	Scientific Name	Farm	Habitat	Status
Rock Dove *	*Columba livia*	C	F	
Rough-winged Swallow	*Stelgidopteryx ruficollis*	B	FM	
Rudy-throated Hummingbird *	*Archilochus colubris*	B	FM	CC - FWC
Sandhill Crane *	*Grus canadensis*	O	FM	T – FWS
Summer Tanager *	***Piranga rubra***	**B**	**FM**	
Turkey Vulture	*Cathartes aura*	C	FM	
Western Palm Warbler *	*Dendroica palmarum*	B	FM	CC - FWC
White Ibis	*Eudocimus albus*	B	FM	SSC – FWC
White-eyed Vireo	*Vireo griseus*	B	M	
Wild Turkey *	*Meleagris gallopavo*	B	FM	CC - FWC
Yellow-billed Cuckoo	*Coccyzus americanus*	B	M	CC - FWC
Yellow-shafted Flicker	*Colaptes auratus*	B	M	
Yellow-throated Vireo	*Vireo flavifrons*	B	F	

APPENDIX B

BIRD SPECIES OBSERVED ON ORGANIC FARMLANDS OF NORTH-CENTRAL FLORIDA

Table B-1. Species observed within cropped fields or within 50 m of cropped fields of organic farmlands in North-central Florida during the spring growing seasons 1 April through 15 June 2002 and 2003. Those species observed foraging within crop vegetation are indicated with an asterisk.

Common Name	Forager	Scientific Name
Acadian Flycatcher		*Empidonax virescens*
American Crow	*	*Corvus brachyrhynchos*
American Goldfinch		*Carduelis tristis*
American Kestrel	*	*Falco sparverius*
Barred Owl		*Strix varia*
Bay-breasted Warbler		*Dendroica castanea*
Blackpoll Warbler		*Dendroica striata*
Blue-gray Gnatcatcher		*Polioptila caerulea*
Blue-headed Vireo		*Vireo solitarius*
Blue Grosbeak	*	*Guiraca caerulea*
Blue Jay	*	*Cyanocitta cristata*
Bobolink		*Dolichonyx oryzivorus*
Brown-headed Cowbird		*Molothrus ater*
Brown Thrasher	*	*Toxostoma rufum*
Boat-tailed Grackle		*Quiscalus major*
Cape May Warbler		*Dendroica tigrina*
Carolina Chickadee		*Parus carolinensis*

Table B-1. Continued.

Common Name	Forager	Scientific Name
Cattle Egret	*	*Bubulcus ibis*
Carolina Wren	*	*Thryothorus ludovicianus*
Cedar Waxwing		*Bombycilla cedrorum*
Chimney Swift		*Chaetura pelagica*
Common Grackle		*Quiscalus quiscula*
Common Ground Dove	*	*Columbina passerina*
Common Yellowthroat	*	*Geothlypis trichas*
Downy Woodpecker		*Picoides pubescens*
Eastern Bluebird	*	*Sialia sialis*
Eastern Kingbird	*	*Tyrannus tyrannus*
Eastern Towhee		*Pipilo erythrophthalmus*
Eastern Tufted Titmouse		*Parus bicolor*
European Starling		*Sturnus vulgaris*
Eastern Wood-pewee		*Contopus virens*
Fish Crow		*Corvus ossifragus*
Gray Catbird	*	*Dumetella carolinensis*
Great Crested Flycatcher	*	*Myiarchus crinitus*
Great Horned Owl		*Bubo virginianus*
Green Heron		*Butorides striatus*

Table B-1. Continued.

Common Name	Forager	Scientific Name
House Finch	*	*Carpodacus mexicanus*
Indigo Bunting	*	*Passerina cyanea*
Loggerhead Shrike	*	*Lanius ludovicianus*
Mississippi Kite		*Ictinia mississippiensis*
Mourning Dove	*	*Zenaida macroura*
Northern Bobwhite	*	*Colinus virginianus*
Northern Cardinal	*	*Cardinalis cardinalis*
Northern Flicker		*Colaptes auratus*
Northern Mockingbird	*	*Mimus polyglottos*
Northern Parula	*	*Parula americana*
Orchard Oriole	*	*Icterus spurius*
Ovenbird	*	*Seiurus aurocapillus*
Pine Warbler		*Dendroica pinus*
Pileated Woodpecker		*Dryocopus pileatus*
Purple Martin	*	*Progne subis*
Red-bellied Woodpecker	*	*Melanerpes carolinus*
Red-eyed Vireo		*Vireo olivaceus*
Red-headed Woodpecker	*	*Melanerpes erythrocephalus*
Red-shouldered Hawk	*	*Buteo lineatus*
Rudy-throated Hummingbird	*	*Archilochus colubris*

Table B-1. Continued.

Common Name	Forager	Scientific Name
Red-winged Blackbird	*	*Agelaius phoeniceus*
Rough-winged Swallow		*Stelgidopteryx ruficollis*
Sandhill Crane	*	*Grus canadensis*
Summer Tanager	*	*Piranga rubra*
Western Palm Warbler	*	*Dendroica palmarum*
White-eyed Vireo		*Vireo griseus*
White Ibis		*Eudocimus albus*
Wild Turkey	*	*Meleagris gallopavo*
Yellow-billed Cuckoo	*	*Coccyzus americanus*
Yellow-rumped Warbler	*	*Dendroica coronata*
Yellow-throated Vireo		*Vireo flavifrons*

APPENDIX C

BENEFICIAL INSECTS OCCURING ON SUNFLOWER AND CROP VEGETATION

Table C-1. Beneficial insects that were observed to occur in randomly placed 1m scouting plots on sunflower and nearby crop vegetation (within 1m of sunflowers) during spring growing seasons 2002 and 2003. Beneficial insects included arthropod predators, parasitic wasps, and important pollinators representing 30 different families.

Family	Common Name	Benefit
Anthocoridae	Pirate Bugs	predator
Apidae	Honey Bees	pollinator
Asilidae	Robber Flies	predator
Cantharidae	Soldier Beetles	predator
Chrysididae	Cuckoo Wasps	predator
Coccinellidae	Lady Beetles	predator
Danaidae	Milkweed Butterflies	pollinator
Dermaptera	Earwigs	predator
Eulophidae	Eulophid Wasps	parasite
Formicidae	Ants	predator
Gelastocoridae	Big-eyed Bugs	predator
Halictidae	Green Metallic Bees	pollinator
Hesperiidae	Skippers	pollinator
Ichneumonidae	Parasitic Wasps	parasite
Lycaenidae	Gossamer-winged Butterflies	pollinator
Mordellidae	Tumbling Flower Beetles	predator
Mutillidae	Velvet-ants	predator
Mymaridae	Mymarid Wasps	parasite

Table C-1. Continued.

Family	Common Name	Benefit
Oxyopidae	Lynx Spiders	predator
Papilionoidae	Swallowtail Butterflies	pollinator
Pentatomidae	Predatory Stink Bugs	predator
Plutellidae	Diamond-backed Moths	pollinator
Reduviidae	Assassin Bugs	predator
Scarabaeidae	Scarab Beetles	predator
Sphecidae	Sphecid Wasps	parasite
Tenebrionidae	Darkling Beetles	predator
Thomisidae	Crab Spiders	predator
Tiphiidae	Tiphiid Wasps	parasite
Trichogrammatidae	Trichogrammatid Wasps	parasite
Vespidae	Vespid Wasps	parasite

BIOGRAPHICAL SKETCH

Gregory Alan Jones was born in North Platte, Nebraska, and raised in Rochester, New York. He attended the University of Miami in Miami, Florida, where he received a B.A. in music, with a concentration in audio engineering, in 1984. In this same year Gregory married and over the next few years began a family while working in the restaurant and entertainment industry. After Gregory's youngest of two sons began school, he enrolled at the State University of New York's College at Brockport where he received a B.S. magna cum laude in biology in 1995. He continued at SUNY Brockport and received an M.S. in biology, with a concentration in avian and terrestrial ecology, in 1997. During this time he served as a research associate at the Braddock Bay Bird Observatory in Rochester, New York.

In the summer of 1996 Gregory moved his family to Gainesville, Florida, and took a teaching position in the Natural Sciences Department of Santa Fe Community College and served as a research assistant to a good friend, Karl Miller, at the University of Florida. Gregory was admitted to the University of Florida's Department of Wildlife Ecology and Conservation in the fall of 1997. He gained tenure at Santa Fe Community College in the summer of 2002. He graduated from the University of Florida with his doctorate in December 2003. Gregory has conducted research in avian community ecology and behavior of

birds in agroecosystems as well as monitoring projects on Neotropical and long distance migratory birds, cavity-nesting birds, and resident birds in New York and Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation fir the degree of Doctor of Philosophy

Kathryn E. Sieving, Chair
Associate Professor of Wildlife Ecology
and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation fir the degree of Doctor of Philosophy

George W. Tanner
Professor of Wildlife Ecology
and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation fir the degree of Doctor of Philosophy

Michael L. Avery
Courtesy Associate Professor of
Wildlife Ecology and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation fir the degree of Doctor of Philosophy

Douglas J. Levey
Professor of Zoology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation fir the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agricultural and Life Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December 2003

Dean, College of Agricultural and Life Sciences

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